PASSING ON DIETARY DIVERSITY?
LIVESTOCK OWNERSHIP IN THE COPPERBELT REGION OF ZAMBIA

BY

MARGARET CHRISTINE JODLOWSKI

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Agricultural and Applied Economics
with a minor in Gender Relations in International Development
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2014

Urbana, Illinois

Master's Committee:

Professor Alex E. Winter-Nelson, Chair
Assistant Professor Kathy Baylis
Assistant Professor Hope C. Michelson

Abstract

Smallholder livestock ownership has potential for nutritional impacts in excess of its effects on income, and may be one method of reducing food insecurity through an increase in dietary diversity. Dietary diversity can be understood both as a measure of macronutrient and micronutrient consumption as well as a household's ability to access a variety of food. As production of animal products tends to have a significant local aspect, there may be spatial spillovers allowing for improved nutrition both for the recipient households and for their communities as well. This research uses a unique dataset from Zambia to measure food security effects, and dietary diversity specifically, of livestock development.

Using a balanced panel of 300 households from the Copperbelt Region of Zambia, this research calculates a Household Dietary Diversity Score (HHDDS) as well as a frequency-weighted dietary diversity score in order to evaluate the impact of receiving livestock on dietary diversity as a measure of food security. By exploiting the staggered rollout of livestock distribution by Heifer International, the organization distributing the livestock, the thesis uses a statistically similar treatment and control group. The results indicate that dairy cows are the most effective livestock studied for improving dietary diversity, both of the households that received them and of their neighbors. However, draft cattle recipient households also see significant improvements in their expenditure per capita, which in turn has a strong, significant, and consistent positive effect on dietary diversity. Thus, livestock improve dietary diversity through both a direct mechanism of consumption of animal products as well as indirectly through an increase in expenditure, some of which is used to purchase a larger variety of food.

Acknowledgements

It goes without saying that I must first thank my advisor, Professor Alex Winter-Nelson, for his unwavering support for me as a student at the University of Illinois. I don't think I would have ever called this department home if not for ACE 251 in 2009. Without his acquiescence, I never would have been able to explore the range and diversity of courses that UIUC has to offer. I will always be grateful to him for that, as well as for fielding all of my worried questions, frenzied deliberations, and always providing timely and thoughtful advice.

The other members of my committee, Assistant Professor Kathy Baylis and Assistant Professor Hope Michelson deserve unending thanks for their careful reads of at least a couple drafts of this thesis but even more so for their advice and encouragement as I made the decision to pursue my Ph.D. I greatly appreciate the time they took to listen to my fears and put up with my deliberations that lasted really up to the 11th hour.

I am also very grateful to Elanco Animal Health (USA) for funding the data collection. This project would not have been possible without their support and the cooperation of Heifer Project International and Heifer Zambia.

To Espresso Royale and all the people in it: thank you for being home.

To Brad, your stubbornness and dedication is a constant inspiration. Having you by my side made this, as all things, a beautiful adventure.

Last, to Mom and Dad, and Eileen and Katherine, my own Modern Family: there are no words except Thank you, thank you, thank you.

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Chapter 1: Introduction

Food insecurity in the developing world can be described both quantitatively as a basic lack of food available for consumption (typically measured in caloric intake) but also qualitatively: the food consumed in the developing world is lower in quality in terms of its nutritional value, especially relative to the diets of those in high income countries. Especially problematic are deficiencies in basic nutrients like protein, vitamin A, and iron, which in turn contribute to low energy, low productivity, and various diseases and disorders. Increasing consumption of these nutrients could therefore be one step to breaking the cycle of poverty and food insecurity in which nutrient deficiencies lead to low productivity which leads to low income and then cyclically to low ability to buy nutrient rich food. Animal products provide many of these crucial nutrients, and so livestock ownership has been increasingly promoted by development-oriented organizations like the FAO as an important part of a food security strategy (FAO 2012).

Because livestock ownership, especially ownership of larger animals like cows or oxen, implies an investment that is beyond most poor households' capacity, NGOs and governments have stepped in to provide these animals as a grant. Some organizations, including Heifer International (HPI), provide animals to households on the condition that the recipient households share the first female offspring of those animals with a neighbor, starting a chain of donations aimed at "achieving self-reliance" and reducing dependence on "handouts" in these communities ("About Heifer," Heifer International). Although this "Passing on the Gift" model has been in place for more than 70 years, most of the analysis of its ability to reduce poverty has been qualitative or anecdotal (see, for example, Kristjanson et al., 2004). Although livestock could play a crucial role in poverty alleviation, few studies have quantified the impact of livestock ownership, and even fewer (if any) have done so through a Framed Field Experiment (FFE).

Using data from the Copperbelt Rural Livelihood Enhancement Support Project (CRLESP), I will be able to fill that gap in the literature. CRLESP is an HPI-implemented project in the Copperbelt Region of Zambia that provides livestock (dairy cows, draft cattle, and goats) to a region with relatively lower rates of livestock ownership (Lubungu et al., 2012). Because of logistical constraints, the distribution of livestock was staggered, such that in my sample population there are equally qualified households that received livestock shortly after baseline and those who have not yet received them. Thus, this staggered rollout scheme has created three treatment groups (one for each of the livestock species) as well as a similar control group, that was randomly designated. Using this randomized setup, I will investigate the impact of livestock ownership on two measures of dietary diversity, as well as expenditure. If livestock ownership has an independent effect on these outcomes, this project would support the FAO's argument that livestock are a useful mechanism for improving the quality and energy content of diets in the developing world.

Chapter 2: Literature Review

This survey of previous research attempts to capture the intersection between three fields of study. The first field is that which looks at the role played by livestock in alleviating poverty or addressing issues of food insecurity in Africa; the second stream of literature examines the value of dietary diversity as a measure of nutritional well-being and food security; the final field is an emergent literature on the spillover effects of nutrition as well as the spatial mechanisms of agricultural technology adoption.

2.1 Livestock and Food Security

Because livestock offer a variety of products and services to households, they are likely to play an important role in the development of agricultural systems and in improving food security. Despite its potential, livestock development has not always been given importance in Poverty Reduction Strategy Plans (PRSPs) or national agricultural development strategies, as Alary et al (2011) point out in their review of the contribution of livestock to poverty reduction. These authors emphasize the importance of proper measurement for increasing recognition of livestock as a poverty reduction strategy, claiming that an income-based measure of livestock-fueled poverty reduction is not sufficient to capture all the contributions of livestock to reducing vulnerabilities for poor households. Thus, an asset or other outcome-based measurement strategy is more appropriate, motivating the decision in this study to look at the effect of livestock on outcomes, rather than just evaluating the income accrual alone. Moll (2003) makes a similar argument in his evaluation of the costs and benefits of livestock ownership, as he emphasizes the nonmarket functions of livestock (including insurance, financing, and status marking). His cost-benefit analysis of livestock in Zambia's Western Province also provides important country-level (though not regional) context for understanding Zambia's livestock system. Moll's analysis only covers families with existing herds of livestock, and thus does not make judgments about the impact of introducing livestock into a household.

Most of the questions asked by Pica-Ciamarra et al (2011) are of little interest to this study, but their discussion of livestock's contribution to household income is certainly relevant. Because of all the services provided by livestock to a household, quantification of their part in household income is not simple. Various studies reviewed by these authors show that livestock's contribution to household income can range from 2% to 24% of total income, depending on the location of the study. These percentages likely do not capture all of the benefits, both monetized and non-monetized, that livestock contribute to a household. Nonetheless, the result that livestock contribute significantly to household income and thus to a household's ability to build an asset base and to purchase food is an important one, and one that informs much of the following discussion. Because their paper was only a survey of previously conducted household surveys, the authors prioritize measurement of the contribution of livestock to households as an area for further research. Upton (2004) also emphasizes the role of livestock in poverty reduction for both a household and national scale. Livestock sector development, he argues, should happen all the way from smallholders to large-scale production and processing of animal products in the developing world. Upton also identifies other areas of support that need to be taken into account when promoting livestock development, including increasing human capital in terms of knowledge of animal care and husbandry and providing access to circulating capital to finance inputs for livestock systems. Essentially, Upton argues that providing an animal through what he calls "'heifer in trust' schemes" is not enough to sustain a livestock sector long term.

The introduction of livestock does not just affect income and other wealth-related measures, but also nutritional outcomes. Livestock's role in creating food security, highlighted in the FAO's "Livestock sector development for poverty reduction" report, is complemented by its role in improving nutrition. Consumption of animal products is "strongly and positively associated" with physical and mental development of children, for example (Otte 2012). At the same time, however, the ability of markets in the developing world to transmit the benefits of livestock consumption through markets for livestock products is still very limited. Further analysis of how these markets work on a micro scale is necessary to understand how these products move through communities and beyond. However, Otte (2012) alleges that direct impacts on incomes through livestock production are likely only to occur in households that already utilize livestock; for households that are new livestock producers, the effects of livestock production improvements are more likely to be felt indirectly, such as through nutritional benefits (Otte 130). Whether or not livestock has an effect on household income as well as effects on nutrition directly (through increased production of animal products) and indirectly (through increased purchasing power from livestock income) is thus an important area of exploration.

The importance of direct consumption of animal products is highlighted by Murphy and Allen (2003), who identify six crucial micronutrients, besides the macronutrient protein, that animal-sourced food provides to children in the developing world. Because of the density of these nutrients in animal-sourced foods (ASF), only a small amount of such foods is required to meet micronutrient gaps, whereas a great deal more plant-based food would be required to cover the same gap. ASF often supplies more than one micronutrient, making it more effective than mono-nutrient supplements. Leroy and Frongillo's (2007) conducted a literature review of studies that evaluated the effects of introducing or enhancing animal production on nutritional status and six other nutritional outcomes, including dietary intake, though not dietary diversity *per se.* While the studies they review describe positive impacts, the authors of the literature review point out major design limitations, including a lack of proper control groups, also noting that studies with direct measurements of animal production on nutritional outcomes are "rare." Thus, my paper is able to overcome these limitations by including a control group and directly measuring the effect of livestock production and ownership on certain nutritional outcomes. Leroy and Frongillo also indicate the importance of identifying whether the nutritional improvements can be ascribed to direct consumption of animal products or as an indirect effect from increased income.

Important contextual and background information about the state of livestock in Zambia itself is provided in Lubungu et al (2012). Their paper relies on three rounds of panel data to determine what motivates participation in livestock markets for Zambian smallholder farmers in addition to capturing the factors that influence market dynamics for Zambian smallholder cattle owners. For one, these authors note that livestock ownership, especially for cattle, is concentrated in the Southern and Eastern provinces of Zambia, with the Copperbelt Province, among others, having relatively low levels of livestock. They also found that education of the household head is a significant indicator of a household participating in the livestock market, with the assumption that more education gives a person a better ability to understand and process market information. It would be interesting to see if such results were consistent in regions where there had been relatively low amounts of livestock, and to see if the introduction of livestock into those areas affected the determinants of market participation and livestock income generation found by these authors. These authors confirm that the Government of Zambia is interested in using livestock as a means to reduce poverty and generate income in the country, as of 2011.

Even when using outcomes other than income to measure the effects of livestock, Mullins et al (1996) point out that the benefits from livestock (specifically dairy cattle) are rarely evenly distributed, and neither is the workload associated with maintaining the animal. While considering livestock like a new agricultural technology, Mullins identifies cases where adoption of the livestock suffered because the benefits (income, etc.) were not distributed proportionately with regards to labor input. These results have important gendered impacts for assessing the outcomes of livestock ownership, as in these cases women were performing most of the work associated with the dairy production. As such, while the increased income and animal product availability may increase health outcomes, for example, the heavier workload may counteract such benefits, negating the positive effects of livestock ownership for those who put in the highest labor input. Income increases that result from dairying are reported in 97% of Mullins's cases; however, her sample is too small to provide statistical conclusions, and the absence of a control group makes ascribing all of the changes (both positive and negative) to livestock very difficult.

Conceptually, it may be productive to think about the introduction of livestock into a household as the introduction of a new agricultural technology into the household.

According to de Janvry et al (2011), staggered rollouts of agricultural technology, such as the Heifer International livestock program in Zambia, can be analyzed similarly to randomized control trials (RCTs) even when they lack explicit randomness. They note that this method will of course require awareness of the context and institutional framework of the rollout. These authors point out the potential selection problem inherent in technology adoption: that those who are adopters are usually fundamentally different than those who are not adopters. Non-adopters of a technology are not always the best control group for adopters for this reason. Analysis of the staggered rollout program structure solves this dilemma because it uses a group of people who wish to be adopters as the control group for adopters. It is much more likely that those who wish to be adopters are similar to those who already are. The authors also note that the use difference-in-differences method for impact analysis is a "growing and welcome trend" but that data limitations have precluded many technology adoption studies from applying it. Thus, the ideal study (in the absence of RCTs), would be one that used difference in differences with treatment and control groups that did not exhibit strong selection bias.

Ssewamala (2004) discusses the influence of the structure of Heifer projects on the expansion of women's opportunities in Sub-Saharan Africa, noting that there are few reports that measure the projects' impact "on women (or anyone else)" using empirical data. While Ssewamala's study looks at a similar program and similar outcomes (including household income and health and nutritional status), it is limited in its discussion of causality by the absence of a control group who did not receive heifers from Heifer International. Spatial and spillover effects are also ignored, as the sample that received questionnaires was solely comprised of livestock recipients. Nonetheless, the author highlights the increased workload livestock ownership entails (especially for women) as an important consideration when evaluating the impact of such projects.

Similarly, Walingo (2009) covers the Kenyan Livestock Development Programme, which has a similar setup to the Heifer projects in that it distributes animals (although they are low-producing but locally adapted zebu cattle) as well as training in animal care and other support mechanisms. The author points out that there are few projects that evaluate the outcomes of livestock programs for the households who benefit from them. Unlike many other studies that do just that, Walingo's study includes a randomly selected treatment group with a non-random control group that was matched on location, age, and economic status with women in the treatment group. The sample size is also larger than many of the other African livestock program impact studies, with 150 beneficiary households in the treatment group and 150 non-beneficiaries in the control. However, this control group is inadequate, as it differs significantly from the treatment group in various categories, including having smaller landholding, less female employment, and lower ability to purchase staples. All of these factors would also significantly impact the nutritional outcomes Walingo wants to measure, and it is unclear without a time dimension (i.e. measurements before and after receipt of the livestock) if these changes were due to the presence of the animal or not. Unsurprisingly, the set of foods that best differentiated the treatment and control groups were consumption of milk and milk products for all members of the household, and those along with meat and green leafy vegetables for preschool aged children. It will be worthwhile to see if these patterns of consumption are replicated in the Zambian context.

Similar difficulty in ascribing causality to livestock can be found in Huss-Ashmore's (1996) study of livestock's nutritional effects in Kenya. The survey sample included only households that owned cattle, and that had previously participated in a study about cattle and disease. This sample group is thus problematic for two reasons: not only does it not include a control group, but households that have a past history of survey participation may for one be more willing to participate in surveys, and may be more invested in the wellbeing of their cattle. The study's instrument for measuring dietary diversity was only applied at the household level, and in some cases on an individual level for only the "woman in charge of the kitchen," precluding intra-household analysis and disallowing analysis on the effects of livestock ownership on children's nutritional outcomes. Also, the nutritional metric in this study was not dietary diversity but rather consumption frequency. Rather than measuring the impact of cattle ownership, this study evaluates differences in nutritional (among other) outcomes based on the number of cattle owned by a household, stratified into small, medium, and large farms. Without a control group, however, it is impossible to ascribe any significance to livestock ownership on its own as influencing food security, as endogenous differences between small, medium, and large farms almost certainly exist. Indeed, Huss-Ashmore does not make any claims of causality, but rather reports percentages and differences in various outcomes based on farm size.

Pimkina et al (2013) have a much better case for causality in their paper, which in its structure and data is similar to my own. They use a similarly structured Heifer International program to investigate the effects of livestock receipt on various biometric outcomes for children and also consumption patterns. However, because of a systematic lack of randomization in the distribution of the livestock, their paper is unable to make statements about causality. Additionally, their paper is based on only one round of survey data, which prevents them from using panel data to control for household-level fixed effects. Thus, rather than the more robust difference in differences method, they rely on Propensity Score Matching (PSM). Nonetheless, they still find significant impacts of livestock ownership (though only for dairy cows) on dietary diversity.

PSM does not control for the problem of unobservables, even as it tries to put a better functional form on the observables for participants in this technology adoption program. According to de Janvry (2011), as discussed above, the livestock distribution programs, like the ones that Heifer International sponsors, can be analyzed as if it were a RCT even without the condition of perfect randomization. Pimkina et al acknowledged the lack of randomization for the Heifer program in Rwanda, but because of a lack of multiple survey rounds were unable to perform difference in differences assessments on the outcomes, which is the ideal method of analysis according to de Janvry. Because my paper uses a balanced panel of four rounds of data for nearly 300 households, I am able to check the consistency of the results using household fixed effects models and am thereby able to better control for endogeneity in the livestock distribution process, as well as for time invariant unobservable differences between households.

This paper also expands on Pimkina et al (2013) by including spatial data that will measure spillover effects into neighboring households who did not receive livestock. Neighbors who will receive offspring of recipients' livestock provide in a sense a secondary control group: while not selected to receive livestock from Heifer, they represent eligible, non-recipient households in the area and allow for analysis of spillover effects of receipt of livestock. Most, if not all, of the papers previously discussed, including Pimkina et al, look only at the effects of livestock on the household that receives it. This work also examines the changes that occur in a household near one that has received livestock.

2.2 Dietary Diversity

Carletto et al (2013) see the lack of international consensus about the proper method of measuring food security as a primary reason that the situation of household food security across the world has not been adequately captured. Measuring food security at the household level is challenging enough, with intra-household distributional effects only compounding the difficulty. Recently, dietary diversity scores have become a popular method of measuring dietary quality and food security. A dietary diversity score is simply the sum of food groups consumed over a time frame at either the household or the individual level. Dietary diversity approximates food security for the simple reason that many nutritional problems are not due to a mere lack of calories but rather to a lack of various nutrients, that theoretically would be supplied through a more diverse diet. Moreover, the tendency for diets to diversify after basic energy requirements are met implies that increased dietary diversity should proxy for increased food-energy security. The Household Dietary Diversity Score (HHDDS) is one such measure of dietary diversity that has been successfully used in the field. While the Food Consumption Score (FCS), a mean of food items consumed, rather than food groups, also captures elements the extent of an individual's or household's dietary diversity, the lack of contextualized cutoff points and food groups (whose optimality vary across regions) is a drawback to this metric of food security. According to the suggestions for measuring household food security given by Carletto et al (2013), surveying households about food consumption data at more than one time during a year will expand current knowledge about seasonality and aggregate consumption throughout the year. They also recommend that, as a "quick win" for improving measurement, surveys collect information about non-standard unit conversions, with the goal of increased ease in cross-survey comparison (Carletto et al 38).

Dietary diversity scores are just one method that can be used to evaluate dietary quality. Another metric, proposed by Murphy and Allen (2003), is the Healthy Eating Index (HEI), which assigns a score based on the nutritional content of a person's daily food intake. While such a metric might do a better job of evaluating the outcome of better nutrition as opposed to just a more diverse diet, such measures are impractical in the Zambian context for many reasons. The nutritional content of food consumed in Zambia may be difficult to determine, and the use of recommended daily values from the Food Guide Pyramid is potentially inappropriate, given the large difference in context between Zambia and the United States that would alter the amounts of various nutrients required. Thus, because improved nutrition cannot directly be used as an outcome for this study, the connection between increased dietary diversity as an intermediate measure and improved nutrition will have to be made by previous literature and applied to this case.

Fortunately, examples abound of such a connection, particularly Hoddinott and Yohannes (2002), who found using data from different study areas that a "1 percent increase in dietary diversity is associated with a 1 percent increase in per capita consumption [and] a 0.7 percent increase in total per capita caloric availability," among other positive relationships with other dimensions of food security (Hoddinott and

Yohannes iii). These authors prioritize dietary diversity not only because it is a viable outcome by itself, but also because it is positively associated with a variety of improved anthropometric and physical outcomes. In terms of data accessibility, dietary diversity can be measured quickly and unobtrusively. Because dietary diversity is strongly related to other measures of food security but is easier and quicker to obtain, it can be considered a more efficient measurement tool for a household or individual's level of access to and utilization and availability of food. These are considered the three dimensions of food security, based on its definition created by USAID. Ruel (2002) expands on their work by delineating further steps that must be taken in order to improve measurement of dietary diversity. In clarifying definitions, she makes it clear that dietary diversity is not a measure of dietary quality, although dietary diversity is correlated with many measures of food security, as demonstrated by Hoddinott and Yohannes (2002). Although Ruel makes this point strongly, it is important to bear in mind that dietary diversity itself can be considered an outcome and that even if it is not a measure of "quality," it is an important indicator. In addition to dietary diversity being associated with measures of food security, Ruel synthesizes a number of studies in which dietary diversity was shown to have a strong, positive, and significant relationship with children's height-for-age Z scores. Other studies she cites show significant association with wasting measures like weight-for-age Z scores and weight-for-height Z scores. Potential confounding effects of socio-economic status, which is correlated positively with dietary diversity measures according to Ruel, necessitate the use of a control group, or some other means of controlling for socioeconomic status.

The Household Dietary Diversity Score (HHDDS) is the preferred means of translating the qualitative record of what a household has eaten into a useable, quantitative metric, according to the FAO Guidelines for measuring dietary diversity. Although this study will use a version of HHDDS that resembles the one recommended by the FAO, these guidelines were published after data collection had already begun and so perfect adherence was not possible. However, the survey practices align with the FAO recommendations in salient ways, including the use of a 24-hour recall period and measurement of dietary diversity during different seasons in an attempt to capture seasonality. The FAO guidelines also state that dietary diversity can be used as an outcome indicator by itself for program evaluation, especially when the program's goal is to improve the availability of certain foods in the market. One of the results of introducing dairy heifers into a community is certainly increasing production diversity (if milk can be thought of as a "crop" in this case). Thus, dietary diversity is an appropriate outcome measure for this study and others that evaluate animal to household donation schemes. In practice, one concern with a 24-hour recall is that it could fail to represent typical eating patterns. One alternative to 24-hour recall is to take into account the frequency at which the food group is served in a week. This could be used to generate a measure of dietary diversity that would be more indicative of typical weekly food group consumption.

It is important to remember throughout this discussion of dietary diversity that nutritional well-being, while often measured at the household level, is individually expressed. This can have significant repercussions when stating the effects of circumstances that alter dietary patterns, including dietary diversity. Villa et al (2011) make this point about the intra-household distribution of dietary diversity in the East African context. Their findings indicate that different members of a households' dietary diversity changes in different ways to increases and decreases in income. Thus, the benefits in terms of dietary diversity from an increase in income are not spread to all members of a household equally, but certain members reap greater benefits. Conversely, during times of stressed income, certain members of the household suffer more than others, perhaps because, using an example from Villa, the household head attempts to shield members of his household from adverse income shocks by reducing his own consumption. This explanation for differences in income elasticities for dietary diversity for various members of a household is in many ways a cultural one, and thus it may not apply in other contexts. Thus, examining the different effects of changes in income on different household members' dietary diversity scores in other regional and cultural contexts beyond the East African pastoralist system would be useful for understanding the general applicability of this work.

In addition to considering the introduction of livestock as the adoption of new technology, it can also be considered a form of agricultural commercialization, creating a useful intersection with previous work on the relationship between agricultural commercialization and nutritional outcomes. DeWalt (1993) summarized the findings of various studies that looked at nutrition and agricultural commercialization. The debate about whether commercialization has a positive or negative effect on nutrition hinges on the question of whether or not the income from commercial activities is spent on more nutritious food. If the income gained commands a supply of nutritious food that would have previously been grown by the household, then the nutritional effects of commercialization would be positive. If the income is not spent in that way, commercialization could be nutritionally detrimental. The crucial factor is, therefore, how the income derived from commercial agricultural activities is spent. While results are mixed about the effect of commercialization, DeWalt identifies certain factors that influence how income from commercialization schemes is spent. The nature of the crop in terms of its likelihood of consumption, the individual who controls production and income, and the ability to continue producing for subsistence all play a role in how well a household is able to improve nutrition while participating in commercial agricultural activities. Thus, it is important to identify the direct effects of the commercial income to best understand its impacts on nutrition.

Taking a similar approach, von Braun (1995) focuses on the process of how commercialization impacts agriculture in addition to making normative policy recommendations for minimizing the potential negative affects of commercialization. The studies von Braun reviewed all use anthropometric outcomes (specifically weight-for-age Z-scores) to measure the nutritional effects of commercialization. In all cases but one, there was a positive and significant effect of income increases on children's Z-scores. However, these results do not differentiate the effects of cash crop or other commercial income, making it less clear what the direct effect of the commercial agricultural activities actually was. Specific studies that evaluate the direct effects of income are a necessary component of this type of analysis, especially if the vehicle for improved anthropometric outcomes (i.e. greater consumption, more nutritionally dense diet, more diversified diet) can be identified.

2.3 Nutritional Spillovers

Control group contamination and other such misstatements of program impact belie the importance of measuring and accounting for spillover effects from technology adoption. de Janvry et al state that it is crucial to account for the spillover effects of technology introduction, and suggest changing the unit of analysis from the individual or household level to the village level to minimize spillovers. However, rather than aggregating households to obscure spillover effects, one can use spatial data from households to measure spillovers from the adoption of a new technology and its byproducts. Positive spillover effects on non-participant households, after all, are not a distortion of the Heifer International program model, but the actual intention.

The literature on peer effects is rapidly developing, and technology adoption in the developing world has also received attention. What is still very much in its developmental stage, is literature on how nutritional outcomes are spread along social networks or even spatially through geographic proximity. Because of limitations of the data, it will not be possible in this study to look for spillover effects on the social network dimension, but it will be possible to use the geographic dimension. Kandpal and Baylis (Working Paper 2013) is one of the initial papers that have used spatial data to understand nutritional effects, though they use peer networks' ability to counter norms as the motivation for understanding how peer networks influence women's empowerment which in turn improves child welfare. For this study, it is less important to consider social networks over geographic dimensions, as the social norms are not being used as a mediating factor for nutrition. There is the possibility, however, that Kandpal and Baylis's hypotheses could be examined in the Zambian context, only with using geographically close networks rather than social networks. Such analysis would add an interesting gendered dimension to the understanding of how nutritional spillovers function. These authors used a woman's identity utility to measure how her choices were influenced by those of her friends; identity utility will also play a role in the geographic dimension of nutritional spillovers, as we can hypothesize that households that live near to a livestock recipient will have utility (in the form of a more diverse diet) from that geographic identity. This paper also found that a program designed to increase women's empowerment can be thought of as a shock to empowerment (just as the Heifer Program can be thought of as a shock to diets) had two effects: the first was the intended program effect and the second was the peer effect, through spillovers of social networks. Their results indicate that for "relatively expensive non-staples," social learning and influence have a strong impact on children's nutritional welfare in terms of dairy consumption. Whether the geographic influence plays a similar role in Zambia remains to be seen. In addition to providing new context and using proximity rather than social networks, this study will also look at the effects of these programs on individuals over time, a temporal dimension that Kandal and Baylis could not access. This will allow for understanding of how spillovers spread over time and diffuse throughout geographic clusters.

As extensive literature on the peer effects of nutrition in the developing world is not available, papers such as Fafchamps (1999), which discusses the role of personal relationships in agricultural commodity markets. Traders in these markets ranked personal relationships the most important factor in business success. Although Fafchamps provides interesting insight into the reasons why personal relationships are important in commodity markets, the paper never specifies what dimension of relationships are valued (i.e. social networks, geographic proximity, etc.) and thus never maps out the way these relationships function in market transactions. For example, while it is interesting to know the percentages of traders that have regular clients (regularity of supply and demand being one of the many stated reasons for the importance of personal relationships), it would be more useful to know spatially how such demand/supply relationships are set up. By focusing only on the percentage with such regular access, we are unable to see the outcomes of this access (or lack of access) to a steady supply of and demand for agricultural products. These results are missing a crucial link to outcomes that researchers and policy makers care about, and do not explain the effects, positive or negative, of personal relationships in business other than they provide a source of regular supply and regular demand. Readers can assume, perhaps, that such regularity provides a higher income, but that connection has not been made explicit.

Other studies that have used spatial data to account for spillover effects in agricultural technology adoption, rather than nutritional effects include Conley and Udry (2001) and (2002). The mechanism of technology adoption in the Heifer programs is the distribution of offspring through the “Pass on the Gift” stipulation. Looking at the spatial nutritional effects of livestock technology adoption can be thought of as understanding how the benefits of a new technology move through spatial networks even when the technology itself affects only certain nodes of that network. Alternatively, a diverse diet can be thought of as a kind of technology in itself, though this is less apparent. The major difference, at least in terms of dairy introduction, from Conley and Udry (2001) is that households in Zambia do not have to observe the functionality of the new technology (whether it is the diverse diet or livestock itself that is labeled thus) to know of its benefits. Although the technology is new in the sense that it was not present in the community to the extent it was following the Heifer program, it was not unknown, which would require a great deal more communication and observation in the social network.

Conley and Udry (2010) place similar emphasis on social learning, while emphasizing that it may be difficult to parse out actual learning from individuals acting like their neighbors for independent reasons. The case of nutritional value chains is shielded from such concern, as it is of course impossible for a household without livestock to act like neighboring households with livestock. They may act like their neighbors in terms of consumption, but they will not be producing animal products. Conley and Udry also use the staggered adoption times of farmers for this technology to analyze the effects of its diffusion over time. Their data is privileged in that they are able to construct data neighborhoods using information like matrilineal clan or church membership; it may be possible in this study to use membership in Heifer International livestock programs, as well as information on social capital such as language spoken in the same way.

Nonetheless, in the absence of such characteristics and measurements, it is necessary to assume that information about the benefits of dairy products, not to mention dairy products themselves, is spread along geographic lines rather than those of the spatial network. For example, because surveying has been completed, it is not possible to place villagers in groups that randomly pair them with other households and see if they have ever gone to the other for advice. While that sort of analysis may be important for a learning situation, it does not apply as neatly to the diffusion of technological innovations (i.e. dietary diversity). It is more likely to consider a farmer going to a nearby household that he/she knows have livestock than going to the person or household he asks for advice more regularly. Based on the work of Conley and Udry (2012) it is safe to assume that the social network for learning is not completely different than that for making purchases of and selling a commodity. For instance, proximity is actually correlated with sharing advice and information with someone, making it an acceptable to use spatial proximity as a proxy for being a part of the same information network.

Bandiera and Rasul (2006) also focus on social learning in the context of adopting a new crop (sunflowers) in northern Mozambique, though their specific emphasis is on the initial adoption of new technology. They study technology adoption in the special case where initial costs do not have to be paid, but rather are provided for by the NGO sponsoring the program. These authors found that there is not a clear, linear relationship that predicts an individual's net gain or loss from adoption. Rather, the outcome of initial adoption is determined by the number of initial adopters are in one's social network. The ideal number of adopters to have in one's social network, according to the results of this study, is between 6 and 10. More than 10 leads to significantly lower results and is no different than having 1 to 5. However, these authors' discussion of determinants of propensity to adopt does not have as much relevance to a program where the technology distribution is pre-determined. It may be useful in terms of understanding how the determination for livestock distribution was made, though the assumption for this study is that it was done randomly among those eligible to receive livestock.

2.4 Conclusion

Although livestock as an agricultural technology and dietary diversity as a goal have both been heavily touted, very few papers have been able to conclusively analyze the impact of livestock ownership on dietary quality. Much has been said anecdotally, but nothing conclusive has been established about the role livestock play in addressing concerns about food insecurity. The studies that have been done ignore the potentially endogenous nature of livestock ownership: establishing an appropriate control group is challenging, as the households without livestock are often those that are unable to sustain ownership financially. The ideal control group would therefore be able to demonstrate both the same interest in and ability to maintain livestock. Furthermore, the presence of livestock in these communities will likely have spillover effects that will not be captured when only looking at the outcome of the recipients. The need to analyze spatial effects, in addition to the necessary statistically similar control group, creates strict stipulations for a data set and an identification strategy that previous studies have been unable to fulfill. Heifer Program rollout in the Copperbelt of Zambia has provided an opportunity to generate the quality of data that has so far been missing.

Chapter 3: Methods

3.1 The Heifer International Program

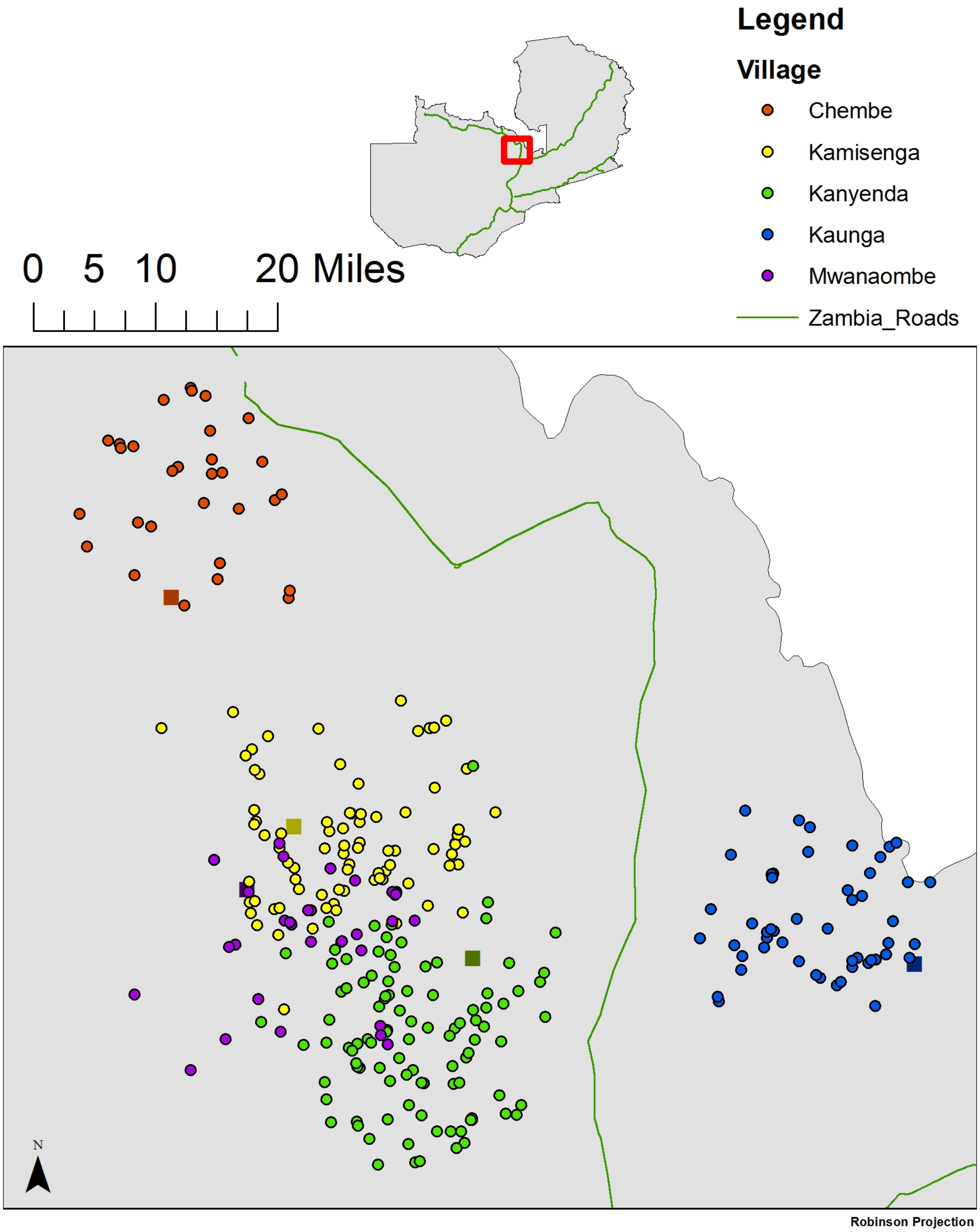
First, it is important to have some understanding of how Heifer Project International (HPI) projects work in rural communities in the developing world. Community groups must first form and organize themselves in order to submit applications to HPI and achieve eligibility for assistance from the organization. Eligibility for individuals in approved groups is also contingent on participation in training activities and initial investments into animal facilities at their homes, as well as payments into a community insurance fund. Thus, the households in groups that are eligible for Heifer assistance may in fact be better off than the average family in Zambia, as eligibility requires significant time and monetary investments. Only a family with some flexible investment power would be able to make such contributions. Moreover, participant households have demonstrated a particular willingness to participate in organized groups. However, it is important to note that even if the eligible participants are different in some ways than the average Zambian household, all the eligible households are similar to *each other* because they all performed the same process of self-selection. Thus, members of eligible community groups could serve as ideal controls for one another. Due to limited supply of pregnant animals, animals are not distributed to every eligible person or group, and households in unserved groups may be a control for those in served groups, while households in served groups that do not receive animals initial are another control. The process to decide beneficiaries is assumed to be random. While eligibility to receive an animal is endogenous and based on self-selection, actual receipt can be considered exogenous.

3.2 The Data

The data used in this analysis comes from the Copperbelt Rural Livelihoods Enhancement Support Project (CRLESP) in the Copperbelt Region of Zambia, which is implemented by Heifer International (HPI) with funding from Elanco Animal Health. The data was collected in 4 survey rounds, starting in January/February 2012 and happening every 6 months after that (June/July 2012, January/February 2013, June/July 2013). This schedule was chosen to capture seasonality effects and fluctuations in food production and consumption, as yearly surveys may observe such fluctuations. This paper will use all four survey rounds, covering a period of 18 months.

Panel data was collected at each of these four rounds from roughly 330 households (the total number varied from round to round), which include nearly 2200 individuals. These households are divided into 5 different communities, and thus can be grouped by their location or by their livestock status, i.e. when they received their livestock (if ever). Three of these communities (Kamisenga, Kaunga, and Kanyenda) contain households that have received livestock from HPI; the remaining two communities (Chembe and Mwanaombe) contain groups that have formed and applied to HPI for livestock assistance. (See Figure 1*)* Thus, there are groups of adopters in some communities and future or would-be adopters in others. Because at least one of these communities is geographically isolated from the others, it is unlikely that spillover effects from neighboring communities' livestock will be present. Additionally, households in the recipient communities that have not yet received their livestock form a control group that may demonstrate spillover effects, allowing for a spatial analysis of the effects of livestock ownership. The two final groups in the sample are those designated to receive offspring from one of the original recipients, a key part of the HPI model, and are known as POGs (for Pass on Gift); the last group are the independents, non-participants in the treated communities who are differentiated by their lack of willingness, ability, or interest in participating. Thus, they do not serve as an ideal control group but rather give insight into the status of the community as a whole. (See Table 7 for summary statistics and balance tests between the 2 groups.)

Figure 1: Map of Project Area Indicating Location of the 5 Villages, Main Roads, and Group Meeting Places (where information about the HPI Program was distributed)



Through the HPI program, the original recipients (or "originals") received different animals based on their community. Kamisenga households received 1 pregnant dairy cow, Kaunga households received 2 draft cattle, and households in Kanyenda received 7 goats. The control communities are both designated to receive dairy or draft cattle, rather than goats. These households will then pass on the first female offspring to POG households, who may or may not receive livestock during the study period; if they do, they would only be receiving immature and nonproductive livestock that are unlikely to yield any income within in the short time period of this study. Thus, this group along with the prospective households in the other communities serves as the control group. This treatment is not an insignificant intervention: the livestock that these households have received are worth 10,000,000 Zambian Kwacha, roughly 10 times the current average asset level of these households.[1] Having an asset of this value is likely to significantly alter the lives of households.

At baseline, enumerators interviewed 324 households. In Round 4, or the third and final follow-up survey, 308 households were interviewed, and of these 308, there were an additional 8 households missing a survey in some round, leaving a final sample size of 300 households. The attrition rate of 8.3% will be problematic if attrition is correlated with treatment status (Angrist, 1997). Of the 24 households not included in the final panel, 13 (54.17%) were POG households, 7 (29.17%) were independents, 3 were original, and the remaining 1 was a prospective. Strangely, 15 of these households were from the same village, Kanyenda, which did have the largest number of participants at baseline as well. These 15 households represent a 13% attrition rate from Kanyenda's

[1] Values in Zambian Kwacha are based on currency prior to currency reform of 2013. The exchange rate is $1 US to ZK 5,000.

original 115 households. Also, this means that running the regressions on a village-by-village basis (i.e. with village-level fixed effects) will remove most of the attrition from the sample.

3.3 The Model

3.3.1 OLS and Difference-in-Differences Model

The purpose of this study is to estimate the independent effect of livestock ownership on dietary diversity, as an indicator for food security. Additional impacts of livestock ownership on total expenditure will also be included, so that an evaluation of livestock's role in addressing poverty can be made. Because expenditure data is considered to be a better indicator of a household's consumption, it will be used instead of income. Expenditure data is more reliable in the sense that it is more closely related to welfare because income is merely a means to consumption. Expenditure also tends to be easier to measure, as income is challenging to track in places where a steady, formalized income is not present (The World Bank, 2005). Consumption (or expenditure) is by no means a perfect measure, especially given the inconsistencies in weights and measures and the need for conversion into a standardized system. Recall may also be imperfect. Here, dietary diversity is used as a proxy for food security, with the assumption being that as families accrue more income, their ability to provide a diverse diet beyond the local starchy staple increases. Dietary diversity can also be thought of as a viable outcome in its own right, as it may be an indicator of a diet richer in certain important nutrients and protein. The ability to purchase animal products and other non-grain food items may also indicate an increase in income, as per Bennett's law.

To analyze the effects of livestock on dietary diversity and food expenditure patterns, two separate models will be used. First, a simple OLS regression that exploits the randomized nature of the livestock distribution is as follows:

$$y_{il} = \alpha + \beta * Treated_l + \mu * CONTROLS_{il} + FE_v + \varepsilon_{il} \qquad (1)$$

Here, *y* is the Household Dietary Diversity Score (HHDDS), probability-weighted DDS, or total expenditure for household *i* in treatment group *l* in the 4^{th} round of data collection. *Treated* is a dummy variable representing treatment (i.e. receipt of livestock from Heifer International), for each of the three treatment groups, which are species specific. $CONTROLS_{il}$ represents the vector of the *i*th household characteristics, including: gender of the household head, natural log of total expenditure, household size, dependency ratio (evaluated as a ratio of the number of children under 16 to the total number of household members), education level of the household head, a measure of wealth based on baseline asset values, and two shock dummies, one for positive shocks and one for negative shocks. Additionally, this model includes village-level fixed effects (FE_v) controlling for unobservable differences between different villages *v*.

This model is valid only if the distribution of livestock within the eligible population was random, and if the effect is strong enough to be demonstrated in the relatively small sample size for this study. It is based on the assumption that the two dietary diversity measures or total expenditures for the originals would be the same on average as the DDS measures or total expenditure of the prospectives or POGs in the absence of the HPI project that distributed livestock to them. Any differences, therefore, can be seen as the result of the Heifer program and the receipt of livestock for the original households.

If, however, the distribution of livestock was not perfectly random this specification may not yield unbiased results. HPI policy is to allow the community livestock group receiving services to determine which households as a group will be original recipients and which households will be POG. This internal process is not documented and may be random or based on a potentially biased selection process. In the case of the latter, the use of household fixed effects would control for this bias. Even if the distribution was random, the sample size may not be large enough to show effects using this specification. Thus, another specification will be implemented, one that uses the difference-in-differences method with fixed group effects as follows:

$$y_{ilt} = \alpha + \beta * After_t * Treated_l + \gamma * After_t + \delta * Treated_l + \mu * CONTROLS_{ilt} + \varepsilon_{ilt} \quad (2)$$

Where y_{ilt} is the desired outcome (either HHDDS, probability-weighted dietary diversity, or total expenditure) for household *i* in species-specific treatment group *l* and round *t*. *After*Treated* is an interaction between the dummy representing an original household and the *After* dummy, representing Rounds 2-4. *Treated* refers to those in the original group who received livestock shortly after the program began. Thus, because there are three different treatment groups as there are three different species, there are three *After*Treated* coefficients; one for each species of livestock. $CONTROLS_{itl}$ would be the collection of control variables from before for household *i* in treatment group *l* and time *t*.

This model specification is based on the assumption that the outcomes for the originals and the prospective and POG groups would change at similar rates in the absence of treatment. That said, the limitations of this model for this specific program include the lack of long-term data that would enable the comparison of trends between the different groups. Without this sort of data, it is harder to establish the parallel trends assumption on which difference-in-differences is predicated. However, the close relationship and similarity between the two groups, such as residing in the same villages and membership in the same livestock support groups required by Heifer International, make a strong case for the similarity of the treated and control groups.

Finally, for added control, I estimate a difference-in-differences model that uses village-level fixed effects, which will control for any unobservable differences among the five villages. This specification uses the following model, which is run with random effects at the household level:

$$y_{ilt} = \alpha + \beta * After_t * Treated_l + \gamma * After_t + \delta * Treated_l + \mu * CONTROLS_{ilt}$$

$$+FE_v + \varepsilon_{ilt} \qquad (3)$$

Where FE is the fixed effects for village *v*; as above, *l* is the species-designated treatment group for household *i* in time *t.* CONTROLS is designated as above.

3.3.2 Spatial Lag Model

When a new agricultural technology or improvement is introduced into a community, it is reasonable to expect that its effects will resonate throughout that community. Given that Heifer International projects specifically include community-level spillovers into their basic premise, any assessment of such programs' effects should also incorporate the indirect effects of the program on those living near recipients who are not direct recipients themselves. Fortunately, it is possible to capture the spatial spillover effects of livestock ownership in this study using the GPS data that were collected for each household and for key community locations. By testing whether the livestock recipients' neighbors demonstrate similar improvements in the dietary outcome variables (such as the Dietary Diversity Score or the probability-weighted dietary diversity), we can begin to understand how the food security benefits of livestock ownership move (or do not move) throughout a community over time. The presence of this outward dispersion of livestock benefits, from the core of the original households to their neighbors, represents additional benefits from the livestock not captured by looking at the outcome effects for the recipients alone. It is reasonable to assume, especially given the above literature on the spatial spillovers of consumption, that the recipients' neighbors (defined either spatially or socially) will positively benefit, as the livestock will produce more than can be consumed by the original household and the excess will be consumed by their friends and neighbors. There are two potential ways in which the spatial spillovers of livestock can be transmitted to neighboring households: through the direct effects of the livestock ownership and indirectly, through the effects of neighboring households' changed outcomes. These effects are both captured in the following spatial lag model, as well as in the spatial panel model in (5):

$$y_{il} = \alpha + \rho * W * Y_{il} + \gamma * W_{Treated_{il}} + \delta * Treated_{il} + FE_v + \mu * CONTROLS_{il} + \varepsilon_{il}$$

(4)

Here, the coefficient on W_y_{il} represents the effect of a household's neighbors' outcome on that household's outcome, whether that outcome is dietary diversity, probability-weighted dietary diversity, or the natural log of total expenditure; this is the indirect effect of a household's livestock ownership on their neighbors. The *W* represents a row-standardized spatial weights matrix that identifies neighbors to any household using a threshold distance of 0.2, where the minimum threshold distance was .184.[2] Thus, W_y_{il} represents the average dietary diversity of all of household *i*'s neighbors. Similarly, the coefficient on $W\_Treated_{il}$ represents the direct effect a household *i*'s neighbors' treatment status (belong to treatment group *l*) has on the outcome variable. Thus, a positive and significant value for ρ indicates that an increase in your neighbors' dietary diversity increases yours as well (and the opposite for a negative value, of course). A positive and significant value for δ indicates that your neighbors belonging to livestock-treatment group *l* increases your dietary diversity (again, vice versa for a negative value). As before, CONTROLS represents a vector of dependent variables and household characteristics, including household size, the gender and education of the household head, natural log of total expenditure, natural log of total household assets at baseline, and two dummy variables for positive and negative shocks. This model was also run with village-level fixed effects.

3.3.3 Spatial Panel

A spatial panel model is necessary to evaluate changes in the outcome variables over space and over time. Because I ran the spatial panel model with both random effects as well as household-level fixed effects, the data had to be cleaned to the point where there were no longer any missing observations. As some households were missing

[2] Minimum threshold distance refers to the shortest distance that would give each household at least one neighbor.

observations for the outcome variables in different rounds (due to a scanning error this information was illegible on the original surveys), they had to be dropped from the spatial panel, leaving a sample size of 1,192 (298 households over 4 rounds). The spatial panel model builds on the spatial lag model above by adding in a temporal component:

$$y_{ilt} = \alpha + \lambda * W * Y_{ilt} + \gamma * W_{Treated_{ilt}} + \delta * Treated_{ilt} + FE_v + \mu * CONTROLS_{ilt} + \varepsilon_{ilt}$$

(5)

The addition of variation over round *t* allows the outcome variable, the treatment effect (both spatially weighted and not spatially weighted), and the time-variant dependent variables to vary from round to round. The random effects specification also includes village level fixed effects. Using household-level fixed effects also controls for unobservable, time-invariant characteristics about the recipient and non-recipient households, which is crucial as there may be some fundamental difference between these households not captured in the data.

3.4 Choice of Outcome Variables

3.4.1 Household Dietary Diversity Score (HHDDS)

Household Dietary Diversity is measured using the method recommended by the FAO for quickly and efficiently evaluating the different food groups a household consumes per week (FAO 2010). Dietary diversity is measured here using a Dietary Diversity Score (HHDDS), which represents a count of the number of food groups consumed by the household over the past 24 hours. Although there is no international consensus on the food groups chosen for inclusion in the DDS measure, the ones that are included in the various measures for DDS are indicators of the purpose of the metric. In the case of the HHDDS metric used here, the 13 food groups are chosen to indicate a household's economic ability to access food: hence the inclusion of purchase-only goods like condiments, sugar, etc. In this study, dietary diversity is used as an outcome given the demonstrated connection between increased dietary diversity and improved nutritional status and food security. Although studies have demonstrated a connection between improved dietary diversity and improved nutritional outcomes, when measuring dietary diversity in this study, we are not measuring nutritional quality but rather food security, or the ability of a household to access a variety of foods, regardless of their nutritional content. Nonetheless, an increase in dietary diversity from one round to the next will be considered a positive outcome. These food groups are recalled by the family member answering the survey and recorded on the survey instrument.[3] The DDS is calculated by adding up the number of consumed food groups, and can take a value of 1–13.[4] The FAO recommends the following nutritional food groups to be used when calculating DDS: 1) Cereals, 2) White tubers and roots, 3) Vegetables, 4) Fruits, 5) Meats, 6) Eggs, 7) Fish and other seafood, 8) Legumes, nuts, and seeds, 9) Milk and milk products, 10) Oils and fats, 11) Sweets, and 12) Spices, condiments, and beverages (FAO, "Guidelines for measuring household and individual dietary diversity").

This study's DDS calculation differs from the above FAO recommendations in a few crucial ways, most notably having 13 categories as opposed to 12. There are two

[3] The households were given the option to have a new respondent take over in this section of the survey so that the person responsible for the preparation of food would be able to respond.

[4] This range is based on the assumption that all households will have eaten something over the past 24 hours and thus have consumed at least one food group. Indeed, there were no households in the sample who answered "No" to all food groups in the 24-hour consumption recall.

tuber categories (white tubers and yellow/orange tubers) as well as two fruit categories (orange or red-fleshed fruit and other fruit). Also, in this study, sweets and beverages were combined into one category. These changes are only minor alterations of the standard FAO recommendations, and serve to better fit the cultural context in Zambia. It is also important to note that the survey instrument differed slightly in this section between Rounds 1 and 2 and Rounds 3 and 4. In later rounds, there were 15 possible food group categories: the vegetables category was expanded to differentiate between dark leafy green vegetables and other vegetables; meat was separated to distinguish between flesh meat and organ meat. However, for the purposes of continuity and due to a lack of consumption of organ meat, these groups were recombined in analysis so that the DDS would be measured the same across all four rounds.[5] For a summary of these differences, see Table 1 below.

Table 1: DDS Categorization

Category	FAO Guidelines	CRLESP Round 1 and 2	CRLESP Round 3 and 4
1	Cereals	Cereals	Cereals
2	White Tubers	White Tubers	White Tubers
3	Vegetables	Yellow/Orange Tubers	Yellow/Orange Tubers
4	Fruits	Dark Leafy Green Vegetables	Dark Leafy Green Vegetables
5	Meat	Orange or Red Fleshed Fruit	Other Vegetables
6	Eggs	Other Fruit	Orange or Red Fleshed Fruit
7	Fish	Meat or Chicken	Other Fruit
8	Legumes, Nuts, Seeds	Eggs	Flesh Meat

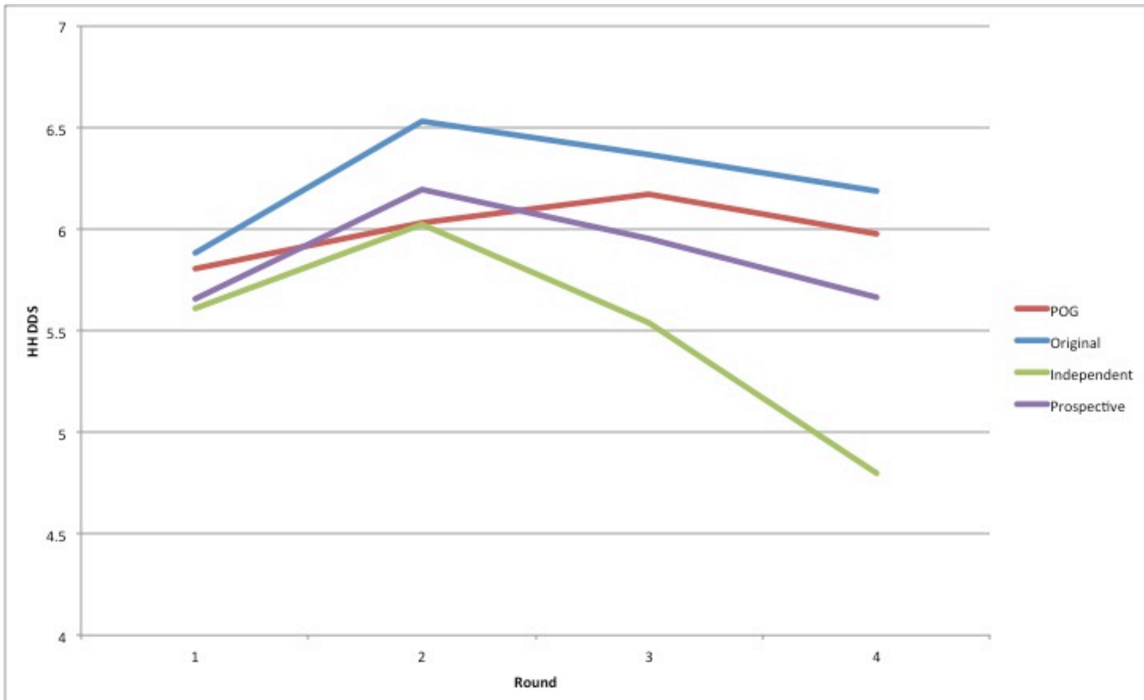
[5] For example, in Round 3, only 8 households reported organ meat consumption in the last 24 hours.

Table 1 (cont.)

9	Milk and Milk Products	Fish	Organ Meat
10	Oils and fats	Legumes, Nuts, Seeds	Eggs
11	Sweets	Milk and Milk Products	Fish
12	Spices, condiments, beverages	Oils and fats	Legumes, Nuts, Seeds
13		Beverages and sweets	Milk and Milk Products
14			Oils and fats
15			Beverages and sweets

Additionally, Figure 2 was created as a primary point of understanding how this metric changes over the four survey rounds and for the different livestock groups. Each point is the average HHDDS for each livestock group in each round. This figure highlights the stark differences between those households in the livestock groups (POG, Original, and Prospective) and those who are not (Independent).

Figure 2: Average HHDDS by Round and Livestock Group



<u>3.4.2 Probability-Weighted Dietary Diversity Score (HHDDS_prob)</u>

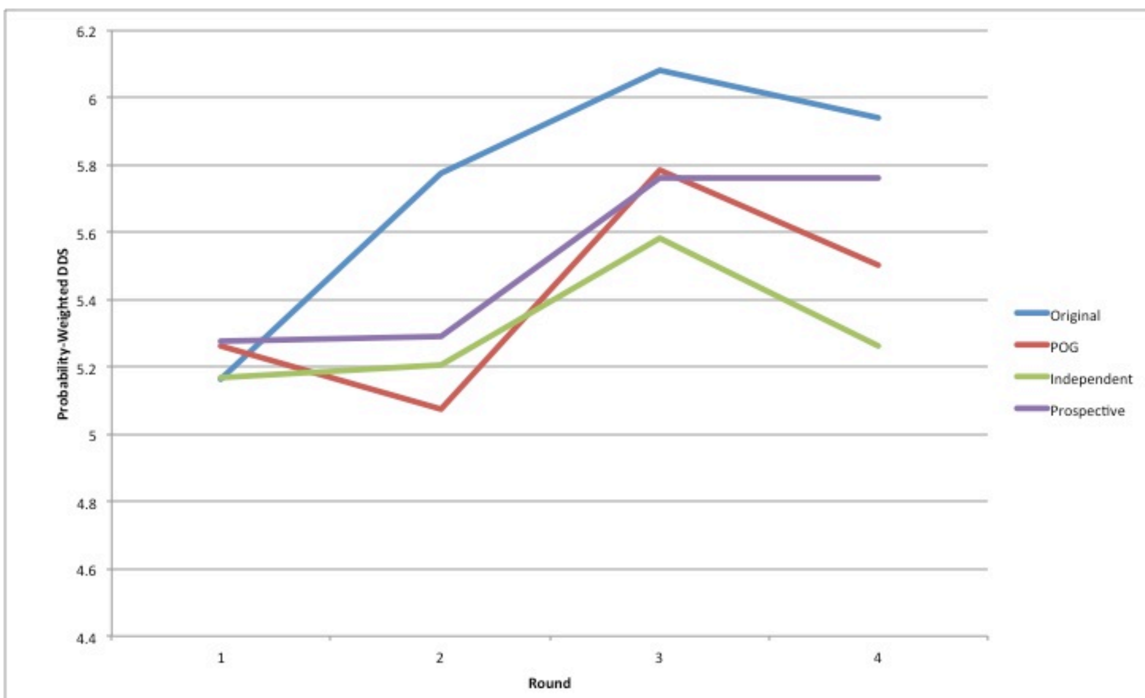
Although the HHDDS captures important information about the consumption patterns of the household and is closely related to their nutritional status, it is not a perfect representation of a household's consumption and may over-state a household's status. For example, if a household only consumed one of the food groups above once a week, but that consumption happened to be in the 24 hour period before the survey was taken, it would appear that their dietary diversity was just as high as a household that ate that same food group every day that week, when that would not be the case. Additionally, in at least one case in Round 4, a household reported no consumption of any food groups over the last 24 hours, giving them a DDS of 0. However, based on their reported frequency of consumption over the last week, data suggest that had the survey been done any other day of the week, their dietary diversity would have could have been a value between 1 and 4. In order to account for these discrepancies and have a more realistic picture of a household's consumption, this study also uses probability-weighted dietary diversity scores as an outcome. Based on reported consumption by food group for the last 7 days, a household that is more likely to have consumed more food groups more often will have a higher probability-weighted DDS than a household that is more likely to consume fewer food groups less often. An increased probability-weighted DDS is assumed to be a positive outcome, although it may not indicate better nutritional status. It is equal to the probability that a household has consumed the first food group (Grains) in the last week, plus the probability that a household has consumed the second food group, and so on through all 13 food groups, as in the following formula:

$\sum_{i=1}^{13} \frac{n_i}{7}$ where *n* is the number of times per week food group *i* is consumed.

Probability refers to the likelihood that the survey would have been performed on a day in which a household had consumed that food group: if they consumed a food group every day, the probability is 1, or 7/7, for example. As with the DDS, the value for the probability-weighted DDS ranges from 1/7 to 13, with a 13 indicating that the likelihood a household ate each food group during the past week is 1, or, that a household ate each food group (See Table 1) every day of the week. The minimum value is not 0, as that would indicate a household ate nothing over the past week; the observable minimum over all households in all rounds is 1.143. In calculating this measure, checks were performed to ensure accurate reporting. Each household that reported consuming a food group in the past 24 hours but not within the last week was checked manually: "unsure" values for the weekly consumption were replaced with the average weekly consumption of that food group for the appropriate livestock group (original, prospective, POG, or independent).

Figure 3 is analogous to Figure 2 in that it provides an initial look at how the average for this metric changes over time for the four livestock groups. Although in Round 1 the average probability-weighted DDS for original recipients is below that of the other two livestock groups, in the following rounds (post treatment) the group's average is noticeably larger, and does not seem as influenced by seasonal-related consumption shocks.

Figure 3: Average Probability-Weighted DDS by Round and Livestock Group



3.4.3 Total Expenditure

It is well reported in the literature that total expenditure is a better measure of household economic well-being than income, especially in a developing country context. Income in these countries may be erratic and piecemeal and thus difficult to record or recall. Expenditure, however, is typically more reliable and gives a more accurate sense of what the economic situation of a household is based on what it is able to purchase. We would expect that livestock ownership leads to an increase in income that will be demonstrated by increased expenditure.

Total expenditure is a necessary control variable because expenditure, as a proxy for income, could be strongly related to increased DDS, especially if increased expenditure is used to purchase a wider variety of food. Measuring total expenditure started with calculating food expenditures and non-food expenditures. Of the two, the calculation of non-food expenditures was relatively easier: for each of the different categories of goods and services that a household indicated they purchased, the value of that purchase was added into the total non-food expenditures. (See Table 2 for categories) Building materials were excluded from this calculation and furniture was depreciated using a 5-year straight-line depreciation, assuming a salvage value of 0. For each household, checks were run to identify any households that responded no to consumption of a category but had a value listed for the category's purchase amount as well as the opposite issue, households that responded yes but had no value listed. Each failed case for either test was manually checked against the original survey and corrected. For the second test, when "unsure" was listed as the value, the predicted values of consumption in this category were imputed from a regression with this consumption category as the outcome and various predictors for that consumption as the dependent variable. (See Appendix A) This predicted values method was done for all non-food consumption categories except for alcohol and cigarettes. In this case, each household that listed an "unknown" or "unsure" amount of alcohol or cigarette consumption was given a value of 1000Kw.

The sum of these amounts equaled the total expenditure per household over the past 3 months: it was then divided by 12 to give the weekly non-food expenditure and to facilitate addition with the food expenditure, which was measured per week.

Table 2: Non-food Expenditure

Number	Non-food Expenditure Category
A	Clothes or shoes for men
B	Clothes or shoes for women
C	Clothes or shoes for children
D	Kitchen equipment (pots etc.)
E	Bedding (blankets, sheets, towels, mattress etc.)
F*	Furniture (sofa, table, bed etc.)
G	Lamps and other electrical items
H**	Building materials
I	Transportation (bus, maintenance of bicycles etc.)
J	Ceremonial expenses (funerals, weddings) and gifts
K	Offerings to church or other group
L	Taxes or levies and fines
M	Medicine or medical care
N	School fees
O	School/educational materials
P***	Cigarettes or tobacco
Q***	Alcoholic beverages
R	Matches, candles, batteries, torches etc.
S	Laundry and bath soap, lotion
T	Costs of telephone (charge, airtime, phone)
U	Fuel (wood, charcoal, kerosene)
V	Total of <u>other</u> consumable goods

* Depreciated using 5-year straight-line depreciation
** Not included in the total sum of non-food expenditures
***Asked last by enumerators

Category H, or building materials, was not included in the calculation due to concerns that the prospective or POG households may increase their building material expenditures in anticipation of receiving an animal. As they are required to provide housing for their livestock, such increases in expenditure would be endogenous to the treatment and thus inappropriate for use in the calculation of one of the most important variables in these regressions. The following table addresses that concern by showing the average building material expenditures for each group in each round.

Table 3: Average Building Materials Expenditure by Livestock Group and Round

	Round 1	Round 2	Round 3	Round 4
Original	151,619.00 (380,427.30)	59,484.62 (352,672.90)	140,883.50 (407,737.90)	120,679.60 (330,187.10)
POG	170,914.40 (1,070,998)	61,742.86 (259,982.80)	313,509.50 (2,120,210)	108,168.30 (378,361.90)
Prospective	78,291.04 (276,885.5)	172,552.20 (533,084.70)	341,567.20 (1,015,969)	215,484.80 (550,213.80)
Independent	14,170.73 (36,092.18)	17,837.84 (83,137.61)	71,459.46 (224,960.60)	19,444.44 (66,802.24)

Standard deviations in parenthesis.

Calculating the value of food expenditure required knowing the means by which the food was acquired: whether it was home-produced, received as a gift, or purchased and also knowing the value for each food item. (See Table 4) First, for each food, the mechanism of consumption (home, gift, or purchase) was determined. If the food was designated purchase only, then the value of that purchase recorded on the survey was used as the value of expenditure for that food group. In the case of solely home-produced or gifted food, the value of consumption was imputed as if it had been purchased. This was achieved by multiplying the amount consumed by a price per unit. For rounds 1 and 2, these values were the same for each village. For rounds 3 and 4, the prices for each food group were dependent on the household's village. (See Table 5 for the average reported prices.) However, there were exceptions to this generally followed process. In round 1, fish, chicken, and meat were recorded together as one food consumption category, and the enumerator recorded the exact value of consumption as if it had been purchased based on the contents of that category for each household. This is the value that was used in calculations for food expenditure and no attempt was made to determine consumption mechanisms or value home-produced meat, chicken or fish. In the remaining three rounds the standard procedure described above was followed for meat, chicken, and fish as separate food categories, with all home-produced fish assumed to be fresh. Two other exceptional food groups were fruits and vegetables: due to the difficulty of standardizing weights, products, and prices for such diverse categories, no attempt was made to value home-produced consumption. When a purchase price was recorded, it was used as the total value of expenditures for these categories. Similarly, other categories (cooking oil and "other goods") were calculated as purchased only because there is typically no home production of these food groups. Thus, this calculation understates the total value of food consumption to some extent.

Table 4: Food Expenditure Categories

Number	Round 1	Rounds 2-4	Unit*
A	Maize	Maize	Kg
B	Rice	Rice	Kg
C	Other grains, groundnuts, beans, peas, lentils	Other grains, groundnuts, beans, peas, lentils	Kg
D	Costs of milling	Costs of milling	-
E	Potatoes or other roots or tubers	Potatoes or other roots or tubers	Kg
F	Vegetables	Vegetables	-

* This represents the standardized units that the recorded values were converted into, if needed, rather than the local units of measurement.

Table 4 (cont.)

G	Fruits	Fruits	-
H	Meat, fish, chicken	Meat	Kg
I	Eggs	Chicken	#
J	Milk	Fish	#
K	Cooking Oil	Eggs	#
L	Bread	Milk	L
M	Pasta	Cooking Oil	L
N	Tea/coffee	Bread	-
O	Sugar	Pasta	-
P	Butter, fat, margarine	Tea/coffee	-
Q	Soft drinks	Butter, margarine, fat	-
R	Salt/spices/seasonings	Soft drinks	-
S	Other	Sugar, salt, spices, seasonings	-
T		Other	-

Table 5: Average Reported Prices for Food Expenditures

Food Group	Average Reported Price (Kw)	Unit of Measurement
Maize	65,000	50kg
Rice	5,600	kg
Other grain	5,025	kg
Potatoes	5,000	kg
Meat	21,900	kg
Chicken	24,500	Number
Fish	11,950	kg
Egg	1,050	Number
Milk	3,980	L

In many cases this process also required conversion from the local units of measurement into the standardized ones that the prices were based on. In cases where the values seemed excessive, as determined by the researcher, manual checking against the original survey was employed in order to ascertain the true intent or meaning of the value consumed. In the case of multiple consumption streams (i.e. purchased and home-produced both indicated), the amount consumed was treated as if it was all home-produced and the procedure above was followed because the percentage of the amount from each consumption stream was not recorded. Treating such cases as if they were only purchased would understate the value of consumption. Once the value of consumption for each food group was acquired, they were summed together to get the total value of food consumption over the week. This value was added to the total weekly non-food expenditure described above for the total expenditure per week. Dividing this value by the household size yielded total expenditure per capita, the value used in the regressions.

3.5 Choice of Explanatory Variables

3.5.1 Household Characteristics

Various household characteristics that are expected to have some impact on household outcome were used as controls. *Household size* will affect the amount a household must purchase and thus may impact dietary diversity; a larger household may sacrifice dietary diversity so that all members can eat, even if they are just eating staple cereals. Thus, all else constant, it is expected that as household size increases, dietary diversity (measured both as HHDDS and as probability-weighted) will fall. Similarly, the number of children, measured as the *dependency ratio,* may have some effect on the outcomes and so is used as a control. In this case, the dependency ratio is calculated by counting the total number of children under age 16 in the household and dividing that number by the total number of members in the household; thus, it ranges from 0 to 1. Just as a larger household may need to sacrifice dietary diversity for staples in order for everyone to eat, a household with a higher dependency ratio may make a similar sacrifice, as it has more non-wage earning members who bring additional costs (school fees, etc.) as well.

Two key characteristics of the household head also warrant inclusion as control variables. The *gender of the household head* is important because female-headed households tend to fare poorly relative to male-headed for a variety of reasons, including differential access to financing, farm inputs, education, and so forth. A female-headed household tends to have lower income as many times it is a "single-parent" household: i.e. one parent is not in the labor force earning a wage while the other stays home to farm. With a male household head, dietary diversity will likely be greater. For this project, determining the household head required a good deal of data cleaning: many households had either two individuals listed as the household head or no one listed, with the adults in the household generally listed as a spouse of the household head. In these cases, the other survey rounds were used to determine who should be listed as head to maintain consistency. Where previous survey rounds proved similarly difficult, the person who was listed as the respondent in the survey round was designated the head. This study also takes *education of the household head* into account as a control variable, with the assumption being that a more educated household head will be more likely to be aware of the benefits of a diverse diet and thus spend a greater amount of income on securing dietary diversity for his or her household. In the cases where the education of the household head was listed as unknown, I imputed the average level of education for a person of the same gender and within the same "age cohort" (i.e. born in the same decade: 20-30 years old, 30-40, 40-50, and so on).

3.5.2 Base Asset Value (Wealth)

In a society where very few households maintain their wealth in cash or other forms of non-durable goods, a household's wealth can be measured by the number and value of “durable good” assets that they own. For this study, the natural log of the total farm assets and household assets for each household from the Round 1 survey were included as controls in the regression. These assets include: hoes, sickles, shovels, slashers, pangas, mortar, sieves, wheel-barrows, sprayers, maize shellers, grain mills, oil presses, and axes for farm-level assets; household-level assets include bicycles, radios, TVs, solar panels or other power sources, automobiles or motor bikes, and beds. The value of each of these assets was summed together if the family owned them to get the total value of the household’s durable assets. The asset level is not considered per capita because many of these items benefit the family as a whole; these benefits would not be diluted by the presence of more members in the household. Wealth, measured by the total value of these assets, is expected to have a strong relationship with dietary diversity, as more wealthy households are able to purchase a more diverse diet than less wealthy ones.

3.5.3 Positive and Negative Shock

The final section of the surveys asked the households if they had experienced shocks, both positive and negative, during the last six months (i.e. since the last survey round). (See Table 6 for a list of the included shocks.) In the model, positive and negative shocks are each represented by a binary variable equal to 1 if the household experienced *any* shock out of the list of positive or negative events. An earlier specification was tested in which shocks were included as a variable equal to the sum of all the shocks the household had experienced, for both positive and negative shocks. However, this did not yield sensible results and so the two binary variables, for positive shocks and for negative shocks, were utilized instead. Each of the potential negative events would likely cause a drop in dietary diversity (as most imply a loss of income in some way) and vice versa for the positive shocks.

Table 6: Shocks

Negative Shocks	Positive Shocks
Illness lasting one week or more	Getting a new job
Injury with recovery time longer than one week	Major business expansion or success
Victim of theft or robbery	New source of remittance income
Victim of other crime	Receipt of large gift or inheritance
Loss of employment	
Major loss or failure in business	
Loss of usual source of remittance/gifts	
Losses due to fire or flood	
Costs of wedding or family event	
Loss of crops due to pests or disease	

3.5.4 Round and Village-Level Fixed Effects

In order to prevent seasonal differences from influencing the results, survey round fixed effects were implemented. This would also prevent any unobserved change from round to round or from the first year to the second from influencing the results. Additionally, village-level fixed effects were also used. While the treatment and control groups on a whole are significantly similar, differences may still exist at the village level (i.e. within the treatment group itself, or between one of the treated villages and the control villages, and so forth). Using village fixed effects prevents these differences, and any other unobservable differences between the five villages, from influencing the results. This is especially important given that the village of Mwanaombe is socially distinct from the others in some unknown way but is not spatially distinct.

3.6 Summary Statistics

The following table presents the means for the full sample, the originals group, and the prospective and POG groups for key variables, measured at baseline. The majority of means for key variables are not statistically different from each other.

Table 7: Sample Means and Standard Deviations, Baseline Survey

	Full Sample Mean	**Received Livestock (Originals) Mean**	**Did Not Receive Livestock (Prospective and POGs) Mean**	**Difference in Means**
n	**315**	**103**	**172**	
Variable				
Household Characteristics				
Number of Children < 6	1.377 (1.061)	1.5 (1.10)	1.278 (1.020)	.222
Number of Children 6-16	1.872 (1.461)	1.967 (1.493)	1.795 (1.434)	.172
Dependency Ratio	.468 (.203)	.453 (.215)	.475 (.196)	-0.022
Household Size	6.883 (2.687)	7.165 (2.474)	6.842 (2.842)	0.323
Education Level of HH Head	3.097 (2.152)	3.216 (3.149)	3.030 (1.453)	0.186
Age of Household Head	46.023 (13.276)	50.784 (12.524)	43.994 (13.509)	6.79*
Count of Female Headed HH	95	29	50 (29 in POG, 21 in Prospective)	-21
Wealth				
Total Expenditure per Capita	35,972.74 (27044.66)	32,801.48 (24,145.39)	38,203.6 (27,164.12)	-5,402.12
Base Household Asset Values	1,490,719 (1,166,861)	1,576,672 (1,079,214)	1,565,961 (1,266,321)	10,711
Food Share as Percent of Total Expenditure	0.563 (.178)	0.552 (.175)	0.560 (.179)	-0.008

Table 7 (cont.)

HH Dietary Diversity Score, R1	5.77 (1.79)	5.86 (1.848)	5.747 (1.774)	0.12

Note: Standard deviations in parenthesis; Values for monetary values given in Zambian Kwacha (exchange rate of approximately 5000Kw to $1USD); Sample does not include "Independents"

- Asset levels cut off at 6,000,000Kw to remove outlier

*Significant at 10%, **Significant at 5%, ***Significant at 1%

There is some concern that, although the Original and POG groups are similar when they are all aggregated together, there may be differences between the different villages. The following Table 8 presents key summary statistics for the different villages by livestock group for key outcome variables.

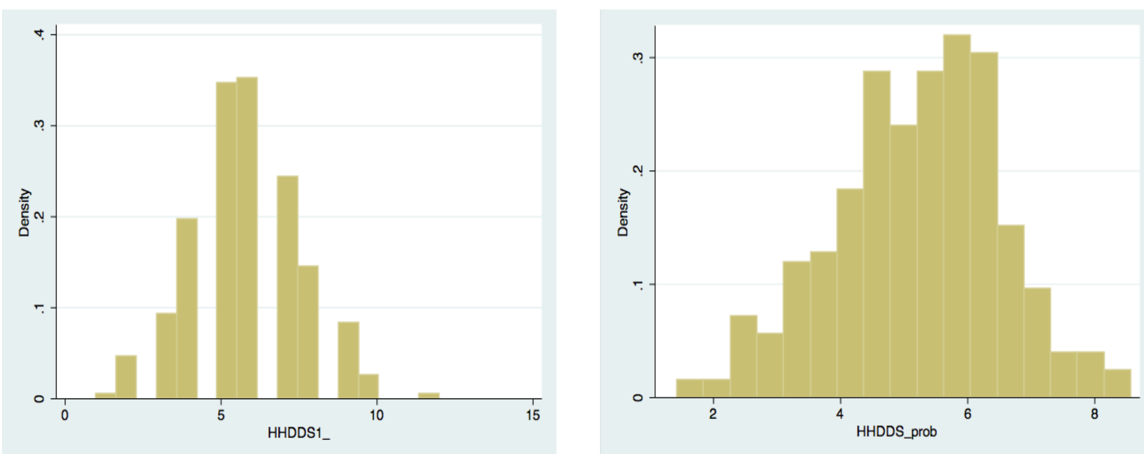
Table 8: Disaggregated Summary Statistics

	n	Total Expenditure per capita	Base Household Asset Values	HHDDS	Probability Weighted DDS
Kamisenga Originals	**32**	33,319.88	2,282,016	6.53	5.70
Kamisenga POG	**39**	26,147.46	1,255,564	5.97	5.16
Kaunga Originals	**20**	32,724.88	2,435,150	7.25	5.91
Kaunga POG	**19**	39,946.43	1,293,421	6.79	6.05
Kanyenda Original	**50**	31,886.30	6,542,790	4.98	4.54
Kanyenda POG	**41**	35,925.44	3,637,980	5.15	4.95
Prospectives	**65**	47,420.48	1,812,350	5.75	5.26
Independents	**33**	28,879.77	1,140,485	5.56	5.15

Chapter 4: Results and Discussion

Although the count nature of the Dietary Diversity score (DDS) and the probability-weighted DDS would typically imply that OLS is not appropriate and that a Poisson or negative binomial model would be better, the distribution of both DDS measure is actually normal (See Figure 4). Thus, results are presented using OLS. Additionally, due to the presence of hetereoskedasticity, robust standard errors are reported throughout. All of the following regressions were run on a sample that excluded the independents group entirely, so that the regressions were run only on the originals and prospective or POG group members.

Figure 4: Distribution of HHDDS and Probability-Weighted DDS in Round 1



4.1 Impact of Livestock Ownership on Dietary Diversity (HHDDS), OLS

The results for the OLS regression are reported in Table 9, in which the Round 4 HHDDS is the outcome of interest. The first specification does not include village-level fixed effects while the second does. In the former, the dairy cow and draft cattle treatments are both positive and significant, indicating that receiving a dairy cow increases household dietary diversity by 0.51 food groups, while receiving draft cattle increases it by 0.71 food groups. In addition to livestock ownership, total expenditure is strongly significant, with a coefficient of 1.28 indicating that increased expenditure is a major driver of consuming a more diverse diet. The education level of the household head is also positive and significant. Finally, the Negative Shock binary variable is strongly significant, indicating that experiencing at least one negative shock (the variable is 1 regardless of how many shocks were experienced) actually increases dietary diversity by nearly one half of a food group. While this result may seem contrary, it is important to remember that in this case dietary diversity is not a measure of nutritional quality. Because the food categories include those that are low in nutritional quality, a negative shock could drive households to consume larger quantities of cheaper, low quality purchased food.

The inclusion of village-level fixed effects makes the coefficient for the draft cattle treatment no longer significant, although dairy cows remain highly significant and with a coefficient equal to 0.80, receiving a dairy cow increases dietary diversity by nearly a whole food group, controlling for the income effect. Once again, natural log of total expenditures, education of the household head, and negative shocks are significant with effects on the outcome variable as before.

Table 9: OLS Regression of HH DDS, Round 4

	(1)	(2)
Dairy cow	0.5079236* (0.2766407)	0.8048318** (0.4011566)
Goat	0.0390051 (0.2473214)	-0.2216884 (0.2920571)
Draft Cattle	0.7093279** (0.3559782)	0.0977967 (0.4356231)
Chembe		0.2547342 (0.3295107)
Kamisenga		-0.0038837 (0.3906171)
Kanyenda		0.5616804* (0.3103174)
Kaunga		0.913017** (0.3705948)
ln Total Assets	-0.0106971 (0.0978852)	-0.0273863 (0.0976089)
Ln Total expenditure per capita	1.275497*** (0.1539399)	1.281651*** (0.1528959)
HH Size	-0.0118092 (0.0388573)	-0.012688 (0.0383449)
Gender of HHH	0.3053163 (0.2048243)	0.3106368 (0.2057598)
Education of HHH	0.2094799*** (0.0741407)	0.187715** (0.0736602)
Dependency Ratio	-0.2974469 (0.4628231)	-0.3511594 (0.4688189)
Negative Shock	0.51460638** (0.2051492)	0.5404069** (0.2104867)
Positive Shock	-0.1381629 (0.2120934)	-0.1025835 (0.2179977)
Constant	-10.77103*** (1.880833)	-10.85512 (1.853371)
F	11.65	9.85
R^2	0.2931	0.3151
n	262	262

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

The OLS results for probability-weighted DDS are shown in Table 10, and once again specification 1 does not include the village-level fixed effects and specification 2 does. The only treatment group that is significant in the first specification is dairy cow, with a corresponding increase in probability-weighted DDS of .48, nearly one half of a food group. As before, increasing expenditure drives most of the increase in dietary diversity, which a coefficient of 1.94. Household size is the final significant coefficient, with increased household size associated with a small (-0.07) drop in probability-weighted DDS. As for the second specification, nothing changes significance with the addition of the village-level fixed effects, none of which are significant themselves.

Table 10: OLS Regression of Probability Weighted DDS, Round 4

	(1)	(2)
Dairy cow	0.5312683** 0.2299497	0.9012475*** (0.2993105)
Goat	0.0331171 0.230156	0.0095733 (0.2935021)
Draft Cattle	0.0202014 0.298714	-0.2032966 (0.3971278)
Chembe		0.1228121 (0.3414273)
Kamisenga		-0.4436201 (0.3251193)
Kanyenda		-0.0507884 (0.3217705)
Kaunga		0.1593258 (0.3678431)
ln Total assets	-0.0671371 0.0953132	-0.0776457 (0.0964624)
ln Total expenditure per capita	1.896889*** 0.1519658	1.89244*** (0.1531011)
HH Size	-0.0495956 0.0340618	-0.0444184 (0.0338941)
Gender of HHH	0.3100583* 0.1665383	0.311023* (0.1662905)
Education of HHH	0.0224758 0.0768693	0.0016308 (0.0768626)
Dependency Ratio	-0.04632 0.4326502	-0.0172067 (0.4410168)
Negative Shock	0.2270362 0.2040921	0.255769 (0.2120341)

Table 10 (cont.)

Positive Shock	-0.0404489 0.2121168	-0.0217311 (0.2212566)
Constant	-17.04806*** 1.803195	-16.79682*** (1.84663)
F	21.64	16.36
R^2	0.4357	0.4453
n	262	262

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

4.2 Impact of Livestock Ownership on Expenditure per Capita, OLS

The OLS results for the final outcome, natural log of total expenditures, are presented in Table 11. Dairy cow is the only significant treatment group, with receipt of a dairy cow resulting in a 22% increase in total expenditure in Round 4. As expected, baseline assets are highly significant in determining expenditure. Household size is also highly significant, with a positive coefficient, indicating that increasing household size also increases expenditure. Finally, the education level of the household head is also positive and significant, which could indicate that the significant effect of education on dietary diversity above is driven by increased expenditure rather than by some increased preference for a diverse diet as a result of being educated, though this is of course speculative.

Table 11: OLS Regression of ln Total Expenditure per Capita, Round 4

	(1)	(2)
Dairy cow	0.177539** (0.0879643)	0.2238608* (0.1162636)
Goat	-0.1157907 (0.0769419)	-0.1691844 (0.1078456)
Draft cattle	0.0771851 (0.1149806)	0.1624762 (0.1519341)
Chembe		-0.0824805 (0.1604622)
Kamisenga		-0.1020691 (0.1289372)

Table 11 (cont.)

Kanyenda		-0.0001153 (0.1269609)
Kaunga		-0.1416407 (0.1429428)
ln Total assets	0.2006575*** (0.0364084)	0.1988868*** (0.0362473)
HH Size	0.0453351*** (0.0129425)	0.0447993*** (0.0127855)
Gender of HHH	-0.0900154 (0.0701482)	-0.0974467 (0.0713662)
Education of HHH	0.0518321* (0.0313377)	0.053943* (0.0310183)
Dependency Ratio	0.1494031 (0.1878993)	0.1544559 (0.1878807)
Negative Shock	0.1060115 (0.0838146)	0.0970299 (0.0848713)
Positive Shock	-0.0020516 (0.0860473)	0.0090346 (0.0889521)
Constant	9.034755*** 90.4632855)	9.121342*** (0.4634462)
F	10.29	7.44
R^2	0.2553	0.2604
n	262	262

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

4.3 Impact of Livestock Ownership on Dietary Diversity (HHDDS) Across All Rounds

Of course, OLS is not the ideal model for this scenario because it does not take into account the variation in these outcome variables over time. Table 12 shows the difference in means for HHDDS, which indicates the usefulness of a difference-in-differences approach for this data: at baseline, the means between the two groups are not significantly different from each other; this changes in the "after" period, defined as Rounds 2-4, with a difference in the means of 0.4. A difference-in-differences framework is ideal for explaining and demonstrating this change.

Table 12: Difference in Means, HH DDS

Variable	No Livestock	Livestock	**Difference**
Before	5.863	5.869	.006
After	5.954	6.359	.405
Difference	.091	.49	**.399**

The results of the difference-in-difference regressions for HHDDS, probability-weighted DDS, and natural log of total expenditure, presented in Tables 13-15, respectively, are the main results of this paper. For all of the following difference-in-difference regressions that used the final balanced panel of 265 households over four rounds (giving 1,060 observations), the regressions were run with random effects at the household level; the standard errors reported are robust standard errors clustered at the household level. The results for DDS in specification 1 (that is, without the village fixed effects) indicate that other factors besides the livestock determine dietary diversity in the after period: neither the coefficient on the after dummy variable nor the coefficients for any of the after-treatment interaction are significant, except for the after-draft cattle interaction, which has a negative coefficient. Instead, expenditure per capita, household size, and education of the household head are all highly significant and positive, with an increase in total expenditure per capita resulting in an increase in DDS of nearly 1 (.828) food groups. Each of the treatment dummies that are not interacted with the time dummy is all highly significant as well. The addition of village level fixed effects in specification 2 provides some of the explanation: the dummies for the villages of Chembe, Kamisenga (which received dairy cows), and Kaunga (which received draft cattle) are all significant, along with, as before, expenditure per capita, household size, and the education of the household head. Additionally, natural log of baseline assets are nearly significant at 10.8% confidence. This indicates that there is something inherent and unobserved about the villages that received the dairy cows and draft cattle that affects dietary diversity and is picked up by the fixed effects. It could be availability of or proximity to markets and shops, or location relative to the roads, for example. The third and final specification is the household fixed effects, which reinforces the non-livestock drivers for standard dietary diversity as an outcome.

Table 13: Panel Regression on HHDDS

	(1)	(2)	(3)
After			0.5957225*** (0.1913814)
Round 2	0.801*** (0.205)	0.810*** (0.205)	
Round 3	0.527*** (0.193)	0.526*** (0.192)	
Round 4	0.175 (0.190)	0.172 (0.190)	
Dairy cow	0.731*** (0.279)	0.466 (0.304)	
Goat	-0.751*** (0.252)	-0.322 (0.267)	
Draft cattle	1.360*** (0.415)	0.576 (0.451)	
After*dairy cow	0.203 (0.313)	0.202 (0.314)	0.266117 (0.30999)
After*draft cattle	-0.621* (0.344)	-0.624* (0.345)	-0.5452256 (0.3434936)
After*goat	0.267 (0.269)	0.264 (0.270)	0.3156741 (0.2719287)
Chembe		0.407* (0.238)	
Kamisenga		0.572** (0.232)	
Kanyenda		-0.131 (0.205)	
Kaunga		1.097*** (0.271)	
ln Expenditure per capita	0.943*** (0.098)	0.957*** (0.095)	-0.7721768 (0.5268931)

Table 13 (cont.)

Dependency ratio	-0.068 (0.298)	-0.031 (0.281)	
ln Total assets	0.057 (0.070)	0.078 (0.066)	0.5413671*** (0.1135883)
Gender of household head	0.045 (0.147)	-0.021 (0.139)	
Household size	0.132*** (0.028)	0.134*** (0.027)	0.0680717 (0.0464222)
Education of household head	0.153*** (0.053)	0.135*** (0.051)	
Negative shock	-0.454*** (0.150)	-0.446*** (0.149)	-0.5247228*** (0.1687218)
Positive shock	0.019 (0.134)	-0.009 (0.135)	-0.0303019 (0.1433127)
Intercept	-6.026*** (1.186)	-6.677*** (1.165)	0.1763631 (1.344855)
F			5.26
R^2	0.2329	0.2609	0.0868
n	1060	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

The results of the difference-in-difference regressions for probability-weighted DDS tell a different story about the effects of livestock ownership, and are summarized in Table 14. Here, the coefficient for the after round interacted with the dairy cow treatment group is positive and significant, with a coefficient of 0.554. Although interpretation of this outcome is not as simple as for DDS, this coefficient can be thought of as more instances of consumption of any food group during a standard week. An instance of consumption here refers to a discrete count of the number of times during the past week a food group was consumed; 7 instances indicate a food group was eaten every day of the week, and thus its likelihood of appearing in the HHDDS count is 100%. Probability-weighted DDS can be thought of as a stricter dietary diversity measurement as it requires consumption of a food group every day to count.

By solving $\frac{n}{7} = .554$ for n gives the number of new instances of consumption per week associated with a 0.554 increase in probability-weighted DDS. In this case, $n = 3.88$. Had, for example, the coefficient been equal to 1, n would equal 7, indicating that a coefficient of 1 makes the likelihood of 7 unique instances of consumption (unique in the sense that they are all distinct from the other; they can be any combination of food groups) 100%. The coefficient for the after term interacted with the goat treatment group is also positive and significant; the coefficient equals 0.365, or the equivalent of 2.56 instances of consumption by the process above. However, the coefficient on the goat treatment alone is -0.625, and so goat ownership in the after period is not enough to offset the fact that goat owners were poorer on average at baseline. Their net consumption is -0.26, or -1.82 instances of consumption, relative to the average household in the sample. As before for HHDDS, expenditure per capita and household size all have a positive and significant effect on probability-weighted dietary diversity, as does experiencing a positive shock. It is interesting to note that positive shocks increase probability-weighted DDS (and negative shocks have no effect) while the opposite is true for standard HHDDS: negative shocks decrease HHDDS and positive shocks have no effect. Positive shocks therefore cause increased consumption, but not necessarily of unique food groups, or it would have an effect on HHDDS. Negative shocks do not affect the amount consumed per week, or there would be a significant effect on probability-weighted DDS; instead, negative shocks cause households to drop unique food groups (likely those that are more expensive) and thus consume a less diverse diet.

The addition of village level fixed effects (Specification 2) makes no dramatic changes to the results, as expected. The only village that has a significant coefficient is Kaunga, the draft cattle recipients' village, although the coefficients for draft cattle treatment and after-interacted draft cattle treatment remain insignificant. This indicates some unobservable effect in this village increasing probability-weighted dietary diversity that is unrelated (or at least not directly related) to the receipt of the draft cattle. The positive shock dummy, expenditure per capita, and household size all continue to play a similar role as in the specification without village fixed effects. In Specification 3, HH Fixed Effects, the time-treatment interactions have larger coefficients that in the RE Specifications, with dairy cow recipients seeing their consumption increase by 0.643, or 4.5 consumptions; goat owners have an increase of 0.424, or 2.97 consumptions in the after period. Expenditures per capita play a slightly smaller (though still highly significant) role, providing more support for the relationship between livestock ownership and increased dietary diversity.

Table 14: Panel Regression on Probability-Weighted DDS

	(1)	(2)	(3)
After			0.060 (0.128)
Round 2	0.058 (0.132)	0.060 (0.134)	
Round 3	0.263** (0.126)	0.263** (0.127)	
Round 4	-0.091 (0.149)	-0.091 (0.151)	
Dairy cow	0.418** (0.177)	0.363* (0.200)	
Draft cattle	0.606** (0.267)	0.196 (0.288)	
Goat	-0.625*** (0.181)	-0.405** (0.201)	
After*Dairy cow	0.554*** (0.197)	0.556*** (0.197)	0.643*** (0.192)
After*Draft cattle	-0.274 (0.267)	-0.274 (0.267)	-0.202 (0.258)
After*Goat	0.365** (0.191)	0.366** (0.191)	0.424** (0.192)
Chembe		0.204 (0.170)	

Table 14 (cont.)

Kamisenga		0.160 (0.176)	
Kanyenda		-0.120 (0.164)	
Kaunga		0.519*** (0.181)	
Dependency ratio	0.468** (0.229)	0.492** (0.223)	0.360 (0.466)
ln Total assets	0.022 (0.051)	0.032 (0.052)	
ln Expenditures per capita	1.276*** (0.073)	1.275*** (0.073)	1.122*** (0.095)
Gender of Household Head	0.007 (0.098)	-0.023 (0.096)	
Household Size	0.167*** (0.018)	0.168*** (0.018)	0.229*** (0.032)
Education of Household Head	0.059 (0.037)	0.047 (0.037)	
Negative Shock	0.032 (0.104)	0.036 (0.105)	0.088 (0.113)
Positive Shock	0.232** (0.096)	0.220** (0.096)	0.093 (0.101)
Constant	-9.704*** (0.930)	-9.898*** (0.935)	-8.057*** (1.078)
F			28.28
R^2	0.4151	0.4248	0.3187
n	1060	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

4.4 Impact of Livestock Ownership on Expenditure Across All Rounds

One of the ways to determine if livestock improve dietary diversity directly through increased consumption of animal products, or indirectly through increased expenditure (implying an increase in income from livestock) is to look at the effect of livestock ownership on expenditure per capita. The results for the panel regression on per capita expenditure indicate that livestock do seem to have some effect on expenditure: the coefficients are all significant, though not strongly. The impact ranges from a 16%-17% increase in expenditure (goats and dairy cows, respectively) to a 21% increase (draft cattle). Additionally, a household's assets at baseline, having a male household head, and education level of the household head all are significant determinants of a household's per capita income. Household size, unsurprisingly, has a negative and significant effect on expenditure: unsurprising because we would expect a larger household to have greater needs and thus greater expenditure. Negative shocks also increase expenditure, as most of the negative shocks (see Table 6) would require some sort of financial outlay to recover.

Table 15: Panel Regression on ln Expenditure per Capita

	(1)	(2)	(3)
After			-0.006 (0.062)
Round 2	-0.248*** (0.060)	-0.249*** (0.060)	
Round 3	0.036 (0.056)	0.034 (0.056)	
Round 4	0.165*** (0.062)	0.163*** (0.062)	
Dairy cow	-0.002 (0.095)	0.064 (0.110)	
Draft cattle	-0.011 (0.100)	0.025 (0.129)	
Goat	-0.157 (0.100)	-0.126 (0.115)	
After*Dairy cow	0.156* (0.097)	0.158* (0.098)	0.158† (0.097)
After*Draft cattle	0.206** (0.093)	0.207** (0.094)	0.201** (0.093)
After*Goat	0.161* (0.094)	0.162* (0.094)	0.147 (0.094)
Chembe		0.168 (0.107)	
Kamisenga		-0.059 (0.095)	

Table 15 (cont.)

Kanyenda		-0.020 (0.095)	
Kaunga		-0.023 (0.112)	
Dependency ratio	-0.099 (0.117)	-0.078 (0.116)	-0.096 (0.162)
ln Total assets	0.205*** (0.029)	0.196*** (0.028)	
Gender of Household Head	0.087 (0.056)	0.092* (0.055)	
Household Size	-0.119*** (0.009)	-0.116*** (0.009)	-0.129*** (0.013)
Education of Household Head	0.073*** (0.023)	0.066*** (0.023)	
Negative Shock	0.085* (0.044)	0.088** (0.044)	0.123** (0.053)
Positive Shock	0.072* (0.040)	0.070* (0.040)	-0.049 (0.045)
Constant	7.965*** (0.410)	8.071*** (0.404)	11.198*** (0.115)
F			16.40
R^2	0.3494	0.3576	0.1729
n	1060	1060	1060

†Significant at 10.5%, *Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

In order to further explore the effect of livestock on expenditure, I pooled together all of the livestock recipients, rather than having them separated into distinct species-specific treatment groups. By interacting this original (as the recipients of the livestock are referred to in the data) group with a dummy for each of the rounds, I can analyze the effects of livestock ownership in general round by round. As reported in Table 16, the coefficients on each of the "after" rounds (Rounds 2-4) are all significant, although the coefficient for R2 is negative, indicating perhaps a seasonal decline in consumption due to increased availability of home produced food. Additionally, the R3*original and R4*original interaction terms are both significant and positive:

having received livestock is associated with an 23.1% increase in expenditure per capita in Round 3 and an 30.2% increase in Round 4. Baseline asset levels, household size, and the education level of the household head all contribute significantly to per capita expenditure as before. Also, negative and positive shocks are both significant and positive, indicating that experiencing a negative shock requires increased expenditure in order to overcome the shock. As all of the positive shocks represent a likely increase in income or disposable funds, the positive coefficient indicates a positive relationship between income and expenditure: when one has more money, one spends more money. These results indicate a positive relationship between expenditure and livestock ownership, a trend that increases over time.

Table 16: Panel Regression with Round Dummies and Treatment on ln Expenditure per Capita

	(1)
After	0.0700326 (0.0518032)
R2*Original	-0.0150036 (0.0915492)
R3*Original	0.2310642*** (0.0900911)
R4*Original	0.3017075*** (0.0873709)
Original	-0.0416284 (0.073055)
Chembe	0.1766076** (0.074004)
Kamisenga	-0.015805 (0.0626306)
Kanyenda	-0.0808545 (0.0654228)
Kaunga	0.0108927 (0.0665339)
Dependency Ratio	-0.1532801 (0.0967205)
ln Total assets	0.1951157*** (0.0201889)

Table 16 (cont.)

Gender of Household Head	0.1017551*** (0.0395977)
Household Size	-0.1041679*** (0.0068409
Education of Household Head	0.0659366*** (0.0166925)
Constant	8.022383*** (0.2852506)

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

4.5 Spatial Spillover Effects of Livestock Ownership

4.5.1 Indirect Effects of Neighbors' Livestock

In beginning to understand the spillover effects of livestock ownership, it is important to understand what the indirect effects a household's neighbors' livestock may have on their dietary diversity outcomes. This was captured using both a pooled OLS model, with Round 4 dietary diversity (standard and probability-weighted) as the outcome, and in a difference-in-differences specification using the panel data. The weighted livestock variables were created using a distance-weight measure with a threshold distance of 0.20, where 0.18 had been the minimum threshold distance. The initial exploration with the OLS model indicates that neighbors' livestock have minimal effect; as Table 17 shows, while a household's own ownership of a dairy cow increases their dietary diversity, there is no effect on HHDDS from any of the spatially weighted livestock variables. For the probability-weighted dietary diversity, a household's own dairy cow once again has a positive and significant effect on their outcome. However, in terms of spillovers, it is only a neighbors' goat ownership that has a positive effect, although the result is not highly significant. For both outcomes, some independent variables, such as per capita expenditure, gender of the household head, and household size both have similar coefficients for the both dietary diversity outcomes. The starkest difference is for the education level of the household head: it has a very small and insignificant coefficient for probability-weighted DDS, but for standard HHDDS it is much larger (relatively) and significant. These results seem to indicate that a more educated household head may in fact value a more diverse diet, though these results will have to be checked in the panel specifications that follow.

Table 17: OLS Regression of Treatment and Direct Effects of Neighbors' Livestock

HHDDS	(1)
Dairy cow	0.8911362** 0.4027787
Goat	-0.1521573 0.2958071
Draft cattle	0.2449165 0.4705723
W_Dairy cow	0.8485832 0.6537985
W_Goat	0.2845158 0.4946398
W_Draft cattle	1.823479 1.238566
Chembe	0.3596775 0.3484446
Kamisenga	-0.1978998 0.4526726
Kanyenda	0.5171098 0.3738714
Kaunga	0.3426442 0.6384389
ln Expenditure per capita	1.199744*** 0.1593016
Dependency ratio	0.0361065 0.4929745
ln Total assets	-0.0045378 0.096724
Gender of Household Head	0.3564274* 0.207392
Household Size	0.1620821*** 0.042036

Probability-Weighted DDS	(1)
Dairy cow	0.9819667*** 0.3038641
Goat	0.0939984 0.2951275
Draft cattle	-0.0969521 0.4507725
W_Dairy cow	0.1428988 0.5703278
W_Goat	1.113496** 0.4766092
W_Draft cattle	1.191858 1.379757
Chembe	0.2238106 0.3786527
Kamisenga	-0.3414075 0.3743785
Kanyenda	-0.4385351 0.3661908
Kaunga	-0.1118262 0.7266552
ln Expenditure per capita	1.753611*** 0.1636206
Dependency ratio	0.5087516 0.4557817
ln Total assets	-0.0370223 0.0966586
Gender of Household Head	0.3229554* 0.1777063
Household Size	0.2190694*** 0.0344182

Table 17 (cont.)

Education of Household Head	0.1742606** 0.0750697		Education of Household Head	0.0009183 0.081921
Negative Shock	0.4954349** 0.210259		Negative Shock	0.1899246 0.2079643
Positive Shock	-0.1523586 0.2185031		Positive Shock	-0.0961613 0.2267289
Constant	-9.441611*** 1.823025		Constant	-14.6029*** 1.804121
F	7.81		F	14.39
R^2	0.2931		R^2	0.4174
n	262		*n*	262

When this regression is run using difference-in-differences and the panel data, with random effects at the household level, a household's neighbors' draft cattle ownership is now significant and positive, leading to a 2.25 increase in the household's DDS. There are a few potential explanations for this result: for one, the neighbors could be benefiting from the power of the animal in their own fields and plots but without the burden of caring for it. Another possible explanation is that the draft cattle produce enough milk so that households share it with their neighbors, but these animals do not produce enough milk for it to be worth the time to take it to the milk collection center, as it would be with the more productive dairy cow. However, the after*w_draft coefficient is not significant, and so it is harder to ascribe this result to the introduction of draft cattle into the community. After implementing village fixed effects in Specification 2, the after*w_dairy interaction's coefficient is significant, with the coefficient equal to 1.23. This is evidence for the spillover of livestock products, especially milk, into the consumption streams of recipients' neighbors, leading to a 1.23 increase in their HHDDS. The use of village fixed effects also removes the significance of the treatment group dummies, showing that their significance in Specification 1 could be attributed to characteristics of the village that received them.

Table 18: Panel Regression of HHDDS, Effect of Treatment and Neighbors' Livestock

	(1)	(2)
Round 2	0.800*** (0.206)	0.808*** (0.207)
Round 3	0.526*** (0.193)	0.525*** (0.193)
Round 4	0.172 (0.191)	0.173 (0.190)
Dairy cow	0.772*** (0.292)	0.444 (0.302)
Goat	-0.555** (0.258)	-0.330 (0.266)
Draft cattle	0.684* (0.388)	0.764* (0.429)
After*Dairy cow	0.027 (0.382)	-0.225 (0.405)
After*Goat	-0.006 (0.383)	0.310 (0.390)
After*Draft cattle	-0.302 (0.671)	-0.174 (0.645)
w_Dairy cow	0.137 (0.376)	-0.613 (0.519)
w_Goat	-0.274 (0.271)	0.571† (0.355)
w_Draft cattle[6]	2.242*** (0.514)	2.708*** (0.820)
after*w_Dairy	0.489 (0.494)	1.217** (0.601)
after*w_Draft	-0.940 (1.985)	-1.306 (1.937)
after*w_Goat	0.626 (0.642)	-0.098 (0.673)
Chembe		0.411† (0.254)

[6] This result is robust to different specifications of the W_DRAFT spatial weight variable, and so at the very list is not driven by the manner in which the weights were calculated. Similar results (for both coefficient and the significance) were found with a 4-nearest-neighbors and a 7-nearest-neighbors weight file.

Table 18 (cont.)

Kamisenga		0.815*** (0.255)
Kanyenda		-0.356 (0.236)
Kaunga		-0.007 (0.413)
ln Expenditure per Capita	0.950*** (0.097)	0.941*** (0.095)
Dependency ratio	-0.084 (0.294)	-0.102 (0.282)
ln of Total assets	0.073 (0.066)	0.069 (0.064)
Gender of Household Head	-0.018 (0.141)	-0.029 (0.137)
Household Size	0.133*** (0.028)	0.135*** (0.027)
Education of Household Head	0.132*** (0.051)	0.145*** (0.050)
Negative Shock	-0.457*** (0.150)	-0.443*** (0.150)
Positive Shock	0.028 (0.135)	-0.019 (0.136)
Constant	-6.280*** (1.157)	-6.385*** (1.134)
R^2	0.2563	0.2715
n	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

The results of this regression for probability-weighted DDS show the impact of dairy cows in the community as well. The spatially weighted dairy cow treatment (i.e. a household's neighbors' dairy cow ownership) coefficient is significant, as is the interaction between that treatment and the after dummy. Thus, a household whose neighbors have received a dairy cow can expect an increase in their probability-weighted DDS of 0.796, or the equivalent of eating a food group nearly every day during the week (5.572 instances of consumption). This coefficient actually increases to 1.103 in Specification 2, with the village fixed effects: this is equivalent to eating a certain food group every day of the week.

Table 19: Panel Regression of Probability Weighted DDS, Effect of Treatment and Neighbors' Livestock

	(1)	(2)
Round 2	0.052 (0.134)	0.054 (0.134)
Round 3	0.258** (0.128)	0.256** (0.128)
Round 4	-0.096 (0.151)	-0.098 (0.151)
Dairy cow	0.491*** (0.188)	0.349* (0.207)
Goat	-0.569*** (0.194)	-0.408** (0.201)
Draft cattle	0.311 (0.265)	0.229 (0.293)
After*Dairy cow	0.271 (0.271)	0.165 (0.282)
After*Goat	0.307 (0.254)	0.526** (0.261)
After*Draft cattle	-0.481 (0.453)	-0.624 (0.448)
w_Dairy cow	-0.173 (0.297)	-0.457 (0.389)
w_Goat	-0.111 (0.205)	0.466 (0.296)
w_Draft cattle	0.899*** (0.317)	0.421 (0.446)
after*w_Dairy	0.795* (0.429)	1.101** (0.472)
after*w_Draft	0.611 (1.113)	1.035 (1.049)
after*w_Goat	0.135 (0.442)	-0.365 (0.476)
Chembe		0.209 (0.173)
Kamisenga		0.345* (0.192)
Kanyenda		-0.302 (0.192)
Kaunga		0.355 (0.270)
ln Expenditure per Capita	1.278*** (0.073)	1.273*** (0.073)
Dependency ratio	0.467** (0.229)	0.473** (0.224)

Table 19 (cont.)

Gender of Household Head	-0.018 (0.097)	-0.027 (0.096)
Household Size	0.168*** (0.018)	0.169*** (0.018)
Education of Household Head	0.052 (0.037)	0.058 (0.037)
Negative Shock	0.035 (0.105)	0.044 (0.105)
Positive Shock	0.241** (0.096)	0.218** (0.096)
Constant	-9.661*** (0.928)	-9.795*** (0.926)
R^2	0.4242	0.4314
n	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

4.5.2 Indirect Effects of Neighbors' Livestock and Neighbors' Outcomes

Once again, this third and final model was run first using the pooled data and then with the panel data to look at the before and after effects of livestock receipt. The former was done with a spatial lag model using Maximum Likelihood and with a weights file created using the 5 nearest neighbors. (See the Appendix B for this regression done with the GMM specification.) A household's own dairy cows have a positive effect on HHDDS, with a coefficient equal to 0.802, but it is a household's neighbors' draft cattle that have a positive and significant effect of 1.438. The coefficient on a household's neighbors' own HHDDS, or ρ, is also significant in this model, showing that an increase in a household's neighbors' DDS will increase their DDS by 0.195. This therefore shows two spatial (i.e. from neighbor to neighbor) transmission channels of improved DDS: the first being through neighbors' livestock (specifically draft cattle) and the second indirectly through their neighbors' own increased HHDDS.

Interestingly, in this model with probability-weighted DDS as the outcome, there seems to be only one spatial method of transmission. None of the spatially weighted livestock variables are significant, although a household's own dairy cows remain significant and with a coefficient of 0.78. As before, however, ρ is significant and its coefficient equals 0.15. (Once again, see the Appendix B for this regression with a GMM specification.) Although this effect is not very large, there is evidence of dietary diversity having some spatial relationship. At least in the case of the probability-weighted DDS, this relationship is not mediated through livestock. Similar effects are felt in both outcomes from per capita expenditure and household size. Dependency ratio increases probability-weighted DDS but not standard DDS, indicating that a household with more children may consume food groups more frequently but are not necessarily consuming more diverse food groups. The shock dummy variables are nearly equal, though with opposite signs, in the HHDDS spatial lag regression: experiencing a negative shock decreases HHDDS by nearly one quarter of a food group while experiencing a positive shock increases HHDDS by about the same amount. As before, a positive shock increases probability-weighted DDS, and a negative shock has no effect: positive shocks cause consumption increases, and negative shocks seem to only affect the diversity of the diet, rather than its frequency.

Table 20: Spatial Lag Model

HHDDS	(1)
ρ	.19533***
Dairy cow	0.802465*** (1.008057)
Goat	-0.181316 (0.182624)
Draft cattle	0.373281 (0.159011)
W_Dairy cow	-0.367170 (0.234605)

Probability-Weighted DDS	(1)
ρ	0.15293***
Dairy cow	0.780032*** (0.133576)
Goat	-0.157421 (0.116315)
Draft cattle	-0.124183 (0.171511)
W_Dairy cow	-0.286389 (0.241763)

Table 20 (cont.)

W_Goat	0.475482 (0.3029814)	W_Goat	0.276048 (0.218896)
W_Draft cattle	1.438483** (0.299266)	W_Draft cattle	0.500668 (0.474462)
Chembe	0.262151 (0.651002)	Chembe	0.088238 (0.156484)
Kamisenga	0.433383** (0.213607)	Kamisenga	0.191108 (0.141774)
Kanyenda	-0.236474 (0.193876)	Kanyenda	-0.20072 (0.147959)
Kaunga	0.229255 (0.202265)	Kaunga	0.363983 (0.238232)
ln Expenditure per capita	0.933822*** (0.325410)	ln Expenditure per capita	1.292281*** (0.059818)
Dependency ratio	0.157868 (0.081596)	Dependency ratio	0.481249*** (0.180151)
ln Total assets	0.085862 (0.246299)	ln Total assets	0.04432 (0.039005)
Gender of Household Head	0.042961 (0.053310)	Gender of Household Head	0.028403 (0.078787)
Household Size	0.123991*** (0.107709)	Household Size	0.16295*** (0.015134)
Education of Household Head	0.145365*** (0.020684)	Education of Household Head	0.050025 (0.031203)
Negative Shock	-0.237951** (0.042650)	Negative Shock	0.052862 (0.072618)
Positive Shock	0.238019** (0.098494)	Positive Shock	0.271711*** (0.084976)
Constant	-7.610925*** (0.116200)	Constant	-11.05817*** (0.739788)
n	1192	*n*	1192

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

When this case is tested using the panel data in a spatial panel regression with random effects, each of the treatment groups was run as a separate regression for ease of interpretation. The results for DDS (Table 21) are somewhat underwhelming: the coefficient on the spatially weighted outcome, λ in this case, is significant only for the draft cattle regression, and even there it is only at an 8% confidence level and it is negative. The only consistent results were the strong positive influence of expenditure per capita, household size, and the education level of the household head, as well as the negative impact of negative shocks. Except for the draft cattle, for which a household's own ownership and a household's neighbors' ownership both have a positive and significant relationship (0.80 and 2.36, respectively), the other livestock treatment indicators, whether spatially weighted or not, are insignificant. Thus, it seems that in terms of spatial spillover effects of livestock ownership, the most impact (if not the only impact) can be seen in the recipients of draft cattle and their neighbors.

These results, unfortunately, are not robust to the spatial panel with household-level fixed effects, shown in Specification 4 below. In this case, the effect of a household's neighbors' outcomes (HHDDS, in this case) flips. For this case, λ is now negative and significant, indicating that an increase in a household's neighbors' dietary diversity decreases theirs by 0.38 food groups. While the interaction of the after dummy and the spatially weighted draft cattle measure (after_wdraft) is still significant, it is now strongly negative (coefficient equal to -5.11). The coefficient for the interaction of after and the draft cattle treatment group (not spatially weighted) remain positive and significant, as does household size and expenditure per capita.

Table 21: Spatial Panel Model on HHDDS

	(1) Dairy Cow Treatment	(2) Draft Cattle Treatment	(3) Goat Treatment	(4) HH Fixed Effects
λ	-0.16756	-0.20709* (0.12560)	-0.16568 (0.13194)	-0.37833*** (0.129268)
After	0.549967*** (0.187278)	0.634386*** (0.19109)	0.541946*** (0.190637)	0.698118*** (0.199808)
Dairy cow	0.633195* (0.331848)			
Draft cattle		0.795302* (0.431988)		

Table 21 (cont.)

Goat			-0.410911 (0.286455)	
After*Dairy cow	-0.033475 (0.420434)			0.073191 (0.43413)
After*Draft cattle		-0.06648 (0.678713)		1.347447* (0.767152)
After*Goat			0.16219 (0.420129)	0.58247 (0.448029)
w_Dairy cow	-0.326954 (0.462224)			
w_Draft cattle		2.36054** (1.007065)		
w_Goat			0.425446 (0.381547)	
After*w_Dairy cow	0.730581 (0.811982)			0.404647 (1.122987)
After*w_Draft cattle		-1.183321 (1.621652)		-5.112304** (2.110983)
After*w_Goat			0.200061 (0.71679)	-0.860005 (0.881994)
Chembe	0.366873 (0.324237)	0.394031 (0.331179)	0.410733 (0.325812)	
Kamisenga	0.492101** (0.238293)	0.706572*** (0.212888)	0.74231*** (0.216509)	
Kanyenda	-0.317072 (0.219844)	-0.310927 (0.218599)	-0.317097 (0.26101)	
Kaunga	1.197926*** (0.279684)	0.17048 (0.522078)	1.267665*** (0.282755)	
ln Expenditure per Capita	0.898485*** (0.083482)	0.911919*** (0.083663)	0.910297*** (0.083845)	0.616435*** (0.08972)
Dependency Ratio	0.120904 (0.25964)	0.053894 (0.263603)	0.038478 (0.263124)	-0.450368 (0.408145)
ln Total assets	0.107331* (0.05931)	0.117267* (0.060571)	0.13441** (0.060309)	
Gender of Household Head	0.070154 (0.121088)	0.095753 (0.122608)	0.110837 (0.124004)	

Table 21 (cont.)

Household Size	0.128256*** (0.022098)	0.125404*** (0.022283)	0.131024*** (0.022264)	0.076672** (0.036323)
Education of Household Head	0.158243*** (0.048219)	0.147681*** (0.048888)	0.160918*** (0.049234)	
Negative Shock	-0.498243*** (0.127386)	-0.514144*** (0.127262)	-0.50848*** (0.127908)	-0.48933*** (0.118166)
Positive Shock	0.097783*** (0.114614)	0.089445 (0.11441)	0.082044 (0.115263)	-0.054624 (0.107403)
Constant	-5.679187*** (1.073114)	-5.753385*** (1.086799)	-6.29131*** (1.08204)	
n	1192	1192	1192	1192

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

When looking at probability-weighted DDS as the outcome in the models with household-level random effects (Table 22), none of the spatially weighted and time interacted treatment groups are significant, and neither is λ. These results are consistent with the results in the spatial panel model with household fixed effects, as well, except for λ, which is significant in specification 4. Without significant coefficients on any of the livestock treatment variables, especially those that are spatially weighted, it is once again challenging to attribute these results to the presence of livestock in the communities. However, given the significance of the village-level dummy variables and the village-specific species distribution, there is a chance these variables are taking the significance away from the species variables. Expenditure per capita, the dependency ratio, and household size seem to be the primary driver of dietary diversity for the spatial panel model, with and without random and fixed effects, for both outcomes.

Table 22: Spatial Panel on Probability-Weighted DDS

	(1)	(2)	(3)	(4)
λ	-0.034089 (0.7918299)	0.0021448 (0.0141257)	0.03445 0.12010	0.0820321** (0.041715)
After	0.1325909 (0.1213377)	0.2158* (0.118396)	0.11746 (0.11883)	0.0014645 (0.108121)
Dairy cow	0.3338936 (0.2402885)			
Draft cattle		0.083915 (0.310354)		
Goat			-0.40441* (0.20766)	
After*Dairy cow	0.3122807 (0.309822)			0.6500385** (0.3280823)
After*Draft cattle		-0.603942 (0.508267)		0.3857821 (0.5830306)
After*Goat			0.37585 (0.30984)	0.912546*** (0.3456951)
w_Dairy cow	-0.4137958 (0.3283274)			
w_Draft cattle		0.334211 (0.687104)		
w_Goat			0.36132 (0.2932)	
After*w_Dairy cow	0.8760556 (0.5810818)			0.0472407 (0.7141227)
After*w_Draft cattle		0.857245 (1.218691)		-1.5201766 (1.5440853)
After*w_Goat			-0.1472 (0.54343)	-1.070408 (0.687454)
Chembe	0.1275857 (0.2060921)	0.135205 (0.202817)	0.16718 (0.20118)	
Kamisenga	0.2096975 (0.1729725)	0.404891*** (0.152108)	0.4435*** (0.15516)	
Kanyenda	-0.2783024* (0.152342)	-0.24169 (0.151821)	-0.25474 (0.18924)	
Kaunga	0.5388112*** (0.1786515)	0.481169 (0.334996)	0.58388*** (0.17618)	
ln Expenditure per Capita	1.2529796*** (0.0613934)	1.281886*** (0.062249)	1.2679*** (0.062068)	1.076589*** (0.0653859)

Table 22 (cont.)

Dependency Ratio	0.4758361** (0.1940492)	0.400464** (0.201979)	0.39629** (0.20159)	0.2152772 (0.318848)
ln Total assets	0.0455031 (0.0441652)	0.065898 (0.046406)	0.070873 (0.046231)	
Gender of Household Head	0.0420906 (0.0905686)	0.07357 (0.094472)	0.074357 (0.095457)	
Household Size	0.1692308*** (0.0164215)	0.171299*** (0.016963)	0.17119*** (0.016916)	0.206397*** (0.0275054)
Education of Household Head	0.0640878* (0.0359594)	0.05575 (0.037556)	0.060327 (0.037756)	
Negative Shock	0.0029121 (0.0946312)	-0.015918 (0.095963)	-0.0000178 (0.095895)	0.0862829 (0.0902378)
Positive Shock	0.2152879 (0.0847682)	0.20702** (0.085731)	0.20582** (0.085826)	0.0698827 (0.0810045)
Constant	-9.741668*** (0.7918299)	-10.6060*** (0.817465)	-10.704*** (0.81249)	
n	1192	1192	1192	1192

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis

4.6 Discussion and Mechanisms

The results above demonstrate that, no matter the specification of the model, some variables contribute to a household's dietary diversity, whether that is HHDDS or probability-weighted DDS. Expenditure, somewhat unsurprisingly, plays a key role, as greater expenditure leads to a greater ability to purchase food from a variety of food groups. Livestock ownership, however, does influence dietary diversity through a few mechanisms: the first of course being direct consumption of animal products and by-products. Second, livestock increases dietary diversity indirectly by increasing income, and finally livestock may provide some resiliency in the presence of negative shocks, allowing these households to better weather shocks; however, there is limited evidence of this from initial exploration of regressions that include interactions between the treatment and shock dummies (See Appendix D).

In order to better understand the first mechanism, and specifically which food groups are impacted, I used both total value of milk consumed and total value of meat, chicken and fish consumed as outcome variables.[7] These food groups were chosen because, as animal products, they are most likely to be directly impacted by livestock, and also because they are typically considered a luxury food group, or at the very least are not consumed every day. The results for the milk regression are presented below in Table 23. The impact of dairy cow ownership on milk consumption is strong and significant, as expected; draft cattle also have some impact, while goats do not show any significant impact. The control variables play a similar role as they did when DDS was the outcome: expenditure and household size both have a positive relationship with milk consumption.

Table 23: Panel Regression of Milk Consumption

	(1)	(2)
Round 2	4671.385** (2119.195)	4874.631** (2125.957)
Round 3	2926.838* (1753.562)	3062.261* (1769.212)
Round 4	-2748.251 (2518.5)	-2642.933 (2533.021)
Dairy cow	-215.522 (1754.943)	-2843.734 (2176.472)
Goat	420.217 (1501.354)	390.064 (1808.057)
Draft cattle	2785.012 (2135.295)	2068.112 (2677.829)
After*dairy cow	20370.320*** (4035.363)	20280.890*** (4043.783)
After*draft cattle	13260.750* (8065.764)	13157.590† (8075.754)

[7] These values were calculated using the process described in Section 3.4.3, where the total value of home produced product was multiplied by its market price in order to find a value in Kwacha for total amount consumed. Meat, chicken, and fish were aggregated together for compatibility with the Round 1 Survey Instrument.

Table 23 (cont.)

After*goat	1997.856 (2118.065)	1904.006 (2133.179)
Chembe		-3093.743† (1892.355)
Kamisenga		3061.363* (1808.039)
Kanyenda		426.705 (1763.376)
Kaunga		1025.341 (1932.824)
ln Expenditure per capita	10315.430*** (1748.712)	10611.030*** (1799.209)
Dependency ratio	3099.544 (3259.379)	2535.287 (3295.953)
ln Total assets	670.699 (710.2655)	849.816 (728.9685)
Gender of household head	485.896 (1898.442)	295.878 (1906.322)
Household size	1457.899*** (433.2668)	1416.529*** (425.4603)
Education of household head	-133.336 (673.8741)	21.909 (707.842)
Negative shock	138.909 (1851.32)	-36.933 (1845.601)
Positive shock	-950.223 (2078.351)	-1003.236 (2090.815)
Intercept	-123296.300*** (23046.64)	-128825.900*** (23918.63)
R^2	0.1661	0.1698
n	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

Table 24 shows the results for this regression with the spatially weighted impact of a households' neighbors' livestock, which adds an interesting dimension to the impact of livestock on milk consumption. A household's own livestock and other independent variables have similar impacts as before, with dairy cows and draft cattle both having a positive effect on dairy consumption. However, it is only a household's neighbors' draft cattle, not dairy cows that have a significant impact on its milk consumption. While this might seem counterintuitive and one would think a dairy cow nearby would increase milk consumption for the community, what this result actually indicates is that the dairy cows are producing enough milk to make transporting the milk to the commercial dairy collection point worthwhile, after the family's own needs are met. The negative and significant coefficient on the dairy consumption of draft cattle owners' neighbors is a surprising result, given that the draft cattle do produce some milk.[8]

Table 24: Panel Regression of Milk Consumption, Effect of Treatment and Neighbors' Livestock

	(1)	(2)
Round 2	4613.460** (2130.201)	4697.256** (2136.112)
Round 3	2961.845* (1695.466)	2949.569* (1708.338)
Round 4	-2688.844 (2467.547)	-2741.903 (2494.693)
Dairy cow	-400.651 (1889.301)	-3221.514 (2227.168)
Goat	-353.761 (1666.175)	257.012 (1827.908)
Draft cattle	3056.482 (2461.617)	964.070 (2715.666)
After*Dairy cow	19596.470*** (6024.075)	16098.760*** (6122.934)
After*Goat	3941.408 (4627.048)	4428.737 (4702.894)
After*Draft cattle	44732.860** (21609.75)	40383.250* (21519.44)
w_Dairy cow	2008.241 (2887.688)	-7517.647* (4386.688)
w_Goat	2918.931 (2575.627)	4092.126 (3750.699)

[8] Results for these regressions with meat, chicken, and fish consumption as an outcome are included in Appendix C, as livestock have no impact on this food group either directly or indirectly with the spatial weights. Thus, when livestock ownership has positive impacts on dietary diversity, this increase is not happening through the mechanism of increased meat, chicken, or fish consumption.

Table 24 (cont.)

w_Draft cattle	823.141 (3808.912)	-11828.230 (8880.705)
after*w_Dairy	2266.410 (7977.335)	11906.360 (8509.379)
after*w_Draft	-92405.320** (42821.06)	-79833.550** (42674.36)
after*w_Goat	-4332.117 (8870.793)	-5607.339 (9129.257)
Chembe		-3669.277* (2025.517)
Kamisenga		5458.081** (2340.178)
Kanyenda		-1825.994 (2279.065)
Kaunga		5544.499 (3735.672)
ln Expenditure per Capita	10122.590*** (1686.778)	10451.590*** (1730.949)
Dependency ratio	2719.354 (3263.301)	2543.181 (3250.244)
ln of Total assets	1034.850 (692.8402)	1182.436* (709.6768)
Gender of Household Head	349.623 (1809.546)	349.468 (1793.676)
Household Size	1455.795*** (430.9403)	1469.659*** (429.8849)
Education of Household Head	-240.879 (674.6252)	26.245 (717.3094)
Negative Shock	47.033 (1763.605)	34.475 (1765.669)
Positive Shock	-741.984 (2097.532)	-798.048 (2082.649)
Constant	-126464.100*** (23578.87)	-131832.100*** (24150.63)
R^2	0.1851	0.1908
n	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

As mentioned above, livestock can be contributors indirectly to increased dietary diversity through increased expenditure, assuming, of course, that livestock ownership increases expenditure as a proxy for income. There is the possibility that long-term ownership of livestock could lead to increased income: for instance, if the animals produce viable offspring that could be sold, once the obligation per HPI's stipulations to "Pass on the Gift" has been fulfilled. There are of course other sellable assets, especially the animal byproducts, that the livestock provide; the positive impact of the draft cattle on expenditure per capita for these households could indicate that these households are able to rent out their animals' draft power to their neighbors. Because the survey contains information about the revenue households received from livestock, we are able to explore how livestock increases income. Table 25 below presents the amount of revenue from livestock different livestock groups in different villages received; in order to examine the effects of Heifer-donated livestock more specifically, Table 26 presents the revenue from livestock excluding eggs.

Table 25: Revenue Derived from Livestock Products

	Round 1	Round 2	Round 3	Round 4
Kamisenga Original	5161.29 (26940.80)	373.995 (270.208)	1053384 (1004415)	774525 (1144088)
Kamisenga POG	0 (0)	0 (0)	0 (0)	61463.41 (250455.2)
Kanyenda Original	2745.098 (13428.09)	.60 (4.243)	36140 (146737.60)	23019.61 103266.2
Kanyenda POG	14772.73 (90437.92)	.048 (0.308)	19146.34 (95811.68)	7954.545 (48348.52)
Kaunga Original	480.0 (2146.625)	0 (0)	154875 (385604.9)	44300 (134834.4)
Kaunga POG	421.053 (1835.326)	0 (0)	39473.68 (120852.2)	4736.842 (20647.42)
Prospective	9664.179 (40699.14)	0.821 5.614	57313.43 (246018.8)	7424.242 (42328.77)

Table 26: Revenue Derived from Livestock Products, excluding eggs

	Round 1	Round 2	Round 3	Round 4
Kamisenga Original	4838.71 (26940.8)	373.995 (270.208)	1053384 (1004415)	774525 (1144088)
Kamisenga POG	0 (0)	0 (0)	0 (0)	61463.41 (250455.2)

Table 26 (cont.)

Kanyenda Original	0 (0)	0 (0)	33600 (146938.3)	22235.29 (103286.5)
Kanyenda POG	14090.91 (90433.53)	0 (0)	18780.49 (93600.08)	7272.727 (48241.82)
Kaunga Original	0 (0)	0 (0)	147875 (387656)	44300 (134834.4)
Kaunga POG	0 (0)	0 (0)	0 (0)	0 (0)
Prospective	6641.791 (36941.68)	0 (0)	55298.51 (246202.8)	7424.242 (42328.77)

Standard deviation in parenthesis.

By combining the direct effect of livestock ownership on dietary diversity (i.e. the coefficients on the species specific treatment) and the indirect effect, in which livestock ownership increases expenditure which in turn increases dietary diversity, it is possible to quantify the effect of livestock ownership on the dietary diversity of the households that received animals. Livestock ownership increased the dietary diversity of the dairy cow recipients by 0.884 food groups and of the draft cattle recipients by 1.54 food groups. It seems to have decreased the dietary diversity of goat recipients by -0.633 food groups. These values take into account the direct impact of the livestock, as well as the animals' impact on expenditure and that impact in turn on increasing DDS. It is important to note that the negative effect for the goat recipients is driven by the direct effect; the expenditure effect remains positive.

Of course, livestock can influence dietary diversity directly, and not through the mediation of expenditure, by the consumption of animal products and by-products. There does not appear to be one consistent relationship between livestock and dietary diversity in the after period, however, as the value of the coefficients and the significance differs from specification to specification. In some sense, this can be attributed to the limitations of dietary diversity as an outcome: it is subject both to seasonal (i.e. what is able to be grown) as well as market (what is available for sale) pressures. Thus, the increases in dietary diversity attributable to the livestock that we do see are in the recipients of the dairy cows, animals that are delivered to the households already capable of producing a food group. (Recall that the households receive a pregnant dairy cow.) In addition to the dairy cows, expenditures, household size, and the education level of the household head. Although it is impossible to say with certainty, increased education may lead to increased valuation for a household's dietary diversity, especially as there is no discernable relationship between a household head's education levels and his/her household's expenditures or baseline assets.

Highlighting their differences as outcomes, there are positive and significant results for probability-weighted DDS that are consistent across all model specifications. Both dairy cow and goat ownership have a positive impact on probability-weighted dietary diversity, which takes into account the number of times a food group was consumed in the past week rather than simply checking if the food group was consumed in the past day. Increased probability of eating a diverse diet is just as beneficial an outcome, and that is what the probability-weighted DDS measure attempts to capture: both quality of diet (in the sense that a more diverse diet is higher quality) and quantity of consumption. The goal is that households move from considering certain food groups luxuries that are consumed maybe once a week to consuming them with regularity. Livestock ownership may not be the best vehicle for achieving this objective, as it necessitates a positive impact on both HHDDS as well as the more frequency focused probability weighted DDS. Livestock, especially dairy cows, may be an appropriate means of achieving one of these outcomes.

Chapter 5: Conclusion

Livestock are a controversial agricultural technology: they require expenditure for their maintenance and may significantly increase a household's work burden, an impact that may disproportionately affect women. Livestock ownership, therefore, is not a poverty reduction or food security mechanism that targets the bottom. Participants in the program studied were required to demonstrate a certain asset level by constructing sheds for these animals and paying their dues to the livestock group, and so the results presented here are generalizable only to the extent that other livestock owners can demonstrate similar levels of wealth. The results are not overwhelming, but they are conclusive: livestock, especially dairy cows, do increase dietary diversity, but they do not do it alone. Expenditures have the strongest (in the sense of both magnitude and consistency) effect on dietary diversity, and other household characteristics contribute as well. Still, recipients of the dairy cows seem best equipped, based on this analysis, to overcome the seasonal and market constraints of dietary diversity. In the spatial results that certainly warrant further exploration, the neighbors of those households that received draft cattle show the biggest improvement in dietary diversity, despite the original recipients of these animals having mostly insignificant results.

Although a basic lack of access to sufficient food is a more pressing and urgent concern, food insecurity and malnutrition often appear not as a lack of a certain quantity of food, but rather as a lack of a quality diet. Dietary diversity is one metric that attempts to capture quality or lack thereof, which can present itself as nutrient deficiencies and other dietary setbacks. Dietary diversity, therefore, can be understood in some sense to be a measure of both nutritional quality and/or basic access to food, based on how the metric is calculated. This is predicated on the assumption that once a sustaining level of access to food has been established, a household will then move to diversifying their diet. In this study, dietary diversity was taken as the main outcome, and understood to be a measure of food access rather than nutritional quality.

Dietary diversity is just one of many impacts livestock ownership can have, and so avenues of future research in this study abound. The impact of the livestock received from Heifer International on assets is one such area, as are the as-yet-unexplored subjective measures of poverty and well-being taken in this study's first and last survey rounds. It would also be valuable to understand the impact of livestock on dietary diversity in other contexts, with different levels of market access, proximity to transportation infrastructure, and milk (and other animal by-products) storage capabilities. Much of dietary diversity is tied up into what households are able to buy or produce due to supply side constraints, and so studies that take place in different contexts would provide some of that scope. Ideally, these studies would be able to exploit the staggered rollout of Heifer International's livestock donation, which creates a group of prospective households that have demonstrated the same interest in and ability to own livestock. Without such a framework in place, it would be much more challenging to associate any impacts with the livestock in the communities. Additionally, because spatial spillovers are embedded in Heifer's program model, it may be beneficial to do a longer-term evaluation of those effects, once the POG aspect has had a chance to make an impact, if any.

This study was able to use a balanced panel with four complete rounds of data on nearly 300 Zambian households to evaluate the impact of a controversial treatment on an outcome whose value may not be apparently obvious. Although dietary diversity may seem to be an intermediate outcome, and beneficial only if it leads to other positive outcomes such as improved health or productivity, it is enough of a good to stand on its own, as a signal of ability to access a variety of food. When frequency of consumption is taken into account, as in the probability-weighted DDS, it is a well-rounded indicator of access to food. Although expenditure has the most consistent and positive effect, livestock ownership, especially of dairy cows, can have a part to play, provided a certain level of financial stability has been achieved and demonstrated. These caveats to the conclusions presented here, as well as the context of the Zambian Copperbelt Region, remain crucial to bear in mind in the continued evaluation of livestock distribution programs worldwide.

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Appendix A

In order to ensure that the expenditure values used in the regressions were as accurate as possible and closely reflected the actual expenditure of the households, "unsure" or "unknown" responses to the value of non-food expenditures for various categories of goods were replaced with the predicted fitted values from the regression that follows. This was not performed in cases where the households indicated that there was consumption in that category (with a yes response) but then listed the value as blank or 0. This was only done for categories for which the household indicated that there was consumption and for which they were unable to recall the value. These categories are:

- Clothes or shoes for Men (3)
- Clothes or shoes for Children (2)
- Kitchen equipment (pots etc.) (1)
- Offerings to church or other group (3)
- Medicines or medical care (4)
- School/educational materials (1)
- Fuel (wood, charcoal, kerosene) (1)
- Ceremonial expenses (e.g. funerals, weddings) & gifts (2)
- Costs of telephone (charge, airtime, phone) (5)

The number in parenthesis indicated the number of households for which a value was imputed in that category. The regression took the following form:

$$Consumption_{ci} = \alpha_1 * HHSize + \alpha_2 * GenderHHH + \alpha_3 * AgeHHH + \alpha_4 * depRatio + \alpha_5 * EducationHHH + \alpha_6 * \ln(HHAssets) + \alpha_7 * cultland + \alpha_8 * \ln(expCAP)_{t-1}$$

Consumption refers to the value of consumption for category c, for household i, in time period t. After running this regression, fitted values were predicted and displayed for the households that had unsure or unknown values for consumption.

Appendix B

The following tables contain the results for the GMM specification of the spatial lag model described in Section 4.5.2.

Table 27: Spatial Lag Model, GMM Specification

HHDDS	(1)	**Probability-Weighted DDS**	(1)
ρ	-1.0729e-62** (4.2207e-63)	ρ	-8.1620e-63** (3.2733e-63)
Dairy cow	0.83176*** (0.24814)	Dairy cow	0.80403*** (0.17824)
Goat	-0.11484 (0.21608)	Goat	-0.11041 (0.15521)
Draft cattle	0.38912 (0.31840)	Draft cattle	-0.11044 (0.22870)
W_Dairy cow	-0.16961 (0.44395)	W_Dairy cow	-0.11797 (0.31888)
W_Goat	0.55151 (0.40732)	W_Goat	0.35953 (0.29257)
W_Draft cattle	1.8557** (0.88590)	W_Draft cattle	0.79514 (0.63633)
Chembe	0.20059 (0.30032)	Chembe	0.049579 (0.21572)
Kamisenga	0.45887* (0.26328)	Kamisenga	0.21102 (0.18911)
Kanyenda	-0.31978 (0.27492)	Kanyenda	-0.25496 (0.19747)
Kaunga	0.17353 (0.44669)	Kaunga	0.31227 (0.32085)
ln Expenditure per capita	0.91627*** (0.11135)	ln Expenditure per capita	1.2899*** (0.079982)
Dependency ratio	0.093166 (0.33486)	Dependency ratio	0.43267* (0.24052)
ln Total assets	0.077508 (0.072403)	ln Total assets	0.034606 (0.052006)
Gender of Household Head	0.072407 (0.014651)	Gender of Household Head	0.048404 (0.10524)
Household Size	0.15228*** (0.029987)	Household Size	0.18249*** (0.021539)
Education of Household Head	0.15874*** (0.058182)	Education of Household Head	0.062736 (0.041791)
Negative Shock	-0.22896* (0.13377)	Negative Shock	0.096005 (0.096087)
Positive Shock	0.18350 (0.16012)	Positive Shock	0.21708* (0.11501)

Table 27 (cont.)

Constant	-5.0114*** (1.4729)		Constant	-9.2828*** (1.0579)

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

Appendix C

The following tables show the results of the panel regressions evaluating the impact of livestock ownership on consumption of meat, chicken, and fish.

Table 28: Panel Regression of Meat, Chicken, and Fish Consumption

	(1)	(2)
Round 2	-2837.239 (3322.638)	-2822.554 (3324.016)
Round 3	11777.620*** (3589.24)	11798.530*** (3563.546)
Round 4	12719.860*** (3978.957)	12713.710*** (3998.671)
Dairy cow	1937.587 (4557.536)	1675.890 (4915.43)
Goat	3036.012 (5399.046)	-471.375 (6910.933)
Draft cattle	411.496 (5024.381)	4599.165 (6522.893)
After*dairy cow	-4768.420 (5959.421)	-4860.543 (5981.334)
After*draft cattle	-12731.370** (5224.588)	-12795.910** (5259.348)
After*goat	-2436.869 (7014.918)	-2495.001 (7032.95)
Chembe		-4063.158 (5186.672)
Kamisenga		-369.447 (3606.725)
Kanyenda		2945.043 (5967.397)
Kaunga		-4943.846 (4666.83)
ln Expenditure per capita	38603.270*** (3494.096)	38821.060*** (3553.819)
Dependency ratio	19173.680** (7657.42)	18459.930** (7351.838)
ln Total assets	-1167.689 (1389.186)	-1242.719 (1476.513)
Gender of household head	-3867.166 (2574.029)	-3564.816 (2545.051)

Table 28 (cont.)

Household size	4362.658*** (666.4509)	4315.369*** (655.3408)
Education of household head	1181.265 (1123.452)	1394.870 (1199.983)
Negative shock	4634.800† (2829.527)	4524.778 (2863.768)
Positive shock	1827.069 (3225.424)	2058.061 (3170.507)
Intercept	-391876.300*** (36960.24)	-392634.700*** (36797.92)
R^2	0.3181	0.3200
n	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

Table 29: Regression of Meat, Chicken, and Fish Consumption, Effect of Treatment and Neighbors' Livestock

	(1)	(2)
Round 2	-2761.669 (3349.452)	-2781.357 (3369.127)
Round 3	11820.780*** (3599.633)	11833.930*** (3605.3)
Round 4	12748.370*** (4014.486)	12711.510*** (4029.524)
Dairy cow	640.264 (4835.417)	1957.105 (4984.077)
Goat	2873.684 (6268.53)	-370.970 (6846.848)
Draft cattle	4131.030 (5678.321)	3694.561 (6804.2)
After*Dairy cow	-2418.252 (8476.834)	-1665.215 (8965.432)
After*Goat	272.738 (13001.68)	-4435.648 (14488.02)
After*Draft cattle	-15286.900† (9334.594)	-16408.820 (10346.09)
w_Dairy cow	3623.713 (9047.417)	5127.032 (12654.08)
w_Goat	332.549 (7653.704)	-11222.200 (14147.69)
w_Draft cattle	-10971.330 (9294.631)	-13866.260 (19649.65)

Table 29 (cont.)

after*w_Dairy	-6714.399 (12934.36)	-9200.206 (15422.64)
after*w_Draft	7366.958 (22135.24)	10386.990 (25883.19)
after*w_Goat	-6312.290 (18051.22)	4358.445 (21491.93)
Chembe		-4851.359 (5888.553)
Kamisenga		-3206.047 (5167.706)
Kanyenda		6802.985 (8663.513)
Kaunga		-172.304 (10577.05)
ln Expenditure per Capita	38727.610*** (3525.562)	39065.350*** (3655.3)
Dependency ratio	19310.740** (7876.066)	19150.220** (7611.714)
ln of Total assets	-1213.444 (1383.363)	-1259.002 (1455.846)
Gender of Household Head	-3803.579 (2625.782)	-3570.991 (2584.636)
Household Size	4341.872*** (668.5552)	4313.426*** (666.7321)
Education of Household Head	1267.078 (1157.073)	1265.648 (1197.104)
Negative Shock	4596.398 (2873.116)	4416.383 (2856.116)
Positive Shock	1779.849 (3229.749)	2273.744 (3129.139)
Constant	-392693.400*** (36209.62)	-393971.600*** (36346.39)
R^2	0.3193	0.3216
n	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

Appendix D

The following tables include results for the panel regressions of the three main outcome variable (HHDDS, probability-weighted DDS, and expenditure per capita) with an interaction between the treatment in the after period and negative shock dummy. For these regressions, a positive and significant coefficient indicates a treated household that experienced a negative shock and was resilient in facing that shock. A negative coefficient has the opposite interpretation. The results below demonstrate that while livestock may provide resiliency in terms of probability weighted dietary diversity, these effects are not felt for the HHDDS. Instead, draft cattle owners who experience a shock in Rounds 2-4 actually see a significant decrease in their HHDDS. Additionally, livestock do not seem to provide these households with any resiliency in terms of expenditure, though these impacts are inconclusive considering a negative shock will typically increase expenditure for these households.

Table 30: Regression of HHDDS, Treatment and Shock Interaction

Round 2	0.809*** (0.189)
Round 3	0.536*** (0.177)
Round 4	0.197 (0.178)
Dairy cow	0.753*** (0.253)
Goat	-0.703*** (0.200)
Draft cattle	1.277*** (0.311)
Dairy*Shock	0.216 (0.305)
Draft cattle*Shock	-0.729** (0.362)
Goat*Shock	0.256 (0.222)

Table 30 (cont.)

ln Expenditure per Capita	0.935*** (0.098)
Dependency Ratio	-0.078 (0.298)
ln Total assets	0.060 (0.070)
Gender of Household Head	0.049 (0.147)
Household Size	0.130*** (0.028)
Education of Household Head	0.154*** (0.053)
Negative Shock	-0.459*** (0.174)
Positive Shock	0.016 (0.134)
Intercept	-5.985*** (1.169)
R^2	0.2344
n	1060

Table 31: Regression of Probability-Weighted DDS, Treatment and Shock Interaction

Round 2	0.169 (0.116)
Round 3	0.371*** (0.116)
Round 4	0.028 (0.136)
Dairy cow	0.609*** (0.157)
Goat	-0.537*** (0.164)
Draft cattle	0.429** (0.181)
Dairy*Shock	0.375* (0.205)
Draft cattle*Shock	-0.070 (0.219)
Goat*Shock	0.312* (0.181)
ln Expenditure per Capita	1.276*** (0.073)
Dependency Ratio	0.466** (0.230)

Table 31 (cont.)

ln Total assets	0.020 (0.051)
Gender of Household Head	0.008 (0.099)
Household Size	0.166*** (0.018)
Education of Household Head	0.060 (0.037)
Negative Shock	-0.063 (0.122)
Positive Shock	0.228** (0.096)
Intercept	-9.709*** (0.919)
R^2	0.4132
n	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis

Table 32: Regression of ln Expenditure per Capita, Treatment and Shock Interaction

Round 2	-0.180*** (0.054)
Round 3	0.103** (0.050)
Round 4	0.236*** (0.054)
Dairy cow	0.056 (0.081)
Goat	-0.104 (0.082)
Draft cattle	0.129 (0.100)
Dairy*Shock	0.099 (0.093)
Draft cattle*Shock	0.025 (0.112)
Goat*Shock	0.114 (0.088)
Dependency Ratio	-0.094 (0.117)
ln Total assets	0.204*** (0.029)

Table 32 (cont.)

Gender of Household Head	0.088 (0.056)
Household Size	-0.120*** (0.009)
Education of Household Head	0.073*** (0.023)
Negative Shock	0.047 (0.051)
Positive Shock	0.069* (0.040)
Intercept	7.946*** (0.413)
R^2	0.3474
n	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors recorded in parenthesis